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ENGLAND AND WALES.

SOILS AND SUBSOILS

FROM A SANITARY POINT OF VIEW;
WITH ESPECIAL REFERENCE TO
LONDON AND ITS NEIGHBOURHOOD.

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PREFACE.

Mr. H. B. Woodward's Memoir on "Soils and Subsoils from a sanitary point of view" was published in 1897, and the fact that a large edition has been sold out in eight years is one of many proofs that it has been highly appreciated.

In preparing the new addition no change has been made in the method of dealing with the subject, but new matter has been added, espeeially in the chapter treating of water-supply and drainage ; and the whole work has been carefully revised. The map has been reproduced from the new series Index map of the Ordnance Survey, and the Geology has been revised so as to incorporate the results of the re-survey of parts of the Thames Valley by Messrs. J. Allen Howe and T. I. Pocock.

The Author desires to acknowledge his indebtedness to Dr. H. F. Parsons and Mr. W. Whitaker who have given much valuable advice and information ; to the *Builder* of February 12th, 1898, for certain suggestions which he has adopted ; to the publications of the Local Government Board and the Sanitary Institute ; and to the writings of Mr. F. J. Bennett, who for many years has been an ardent champion of sanitary reform.

J. J. H. Teall,
Director.

Geological Survey Office,
28, Jermyn Street, London,
2nd January, 1906.

8574. 1500—Wt. 2783. 1/06 Wy. & S. 3618*r*. *b*

PREFACE TO FIRST EDITION.

At the Offices of the Geological Survey constant enquiries are made by the public for information regarding sites for houses and other questions involving the practical applications of geological science. In view of this great and ever-increasing demand for advice, it seemed desirable to put in popular and accessible form a summary of what is known as to the relations between the nature of soils and sub-soils and the sanitary requirements of the community, and to select for the purpose of illustrating the subject the district of London and its suburbs.

Accordingly, Mr. Horace B. Woodward has prepared the present treatise. His long connection with the Geological Survey has given him special fitness for the task. Besides a wide acquaintance with the geology of the southern half of England, he formerly took part in the detailed mapping of the London area, and in his capacity as Resident Geologist at this Office he is now thrown into daily contact with those who are practically engaged in well-sinking, draining, building, and other occupations in which geological assistance is sought for. He has thus been able to gather much general information on the subjects discussed in the following pages, his own personal observations being supplemented by those obtained from medical officers, engineers, and architects, as well as from house-hunters who have communicated their various experiences.

In the preparation of this hand-book to the soils and sub-soils of London and its neighbourhood the author has consulted the valuable "Transactions of the Sanitary Institute" and other works, and among those individuals to whom he is more particularly indebted for assistance he desires to express his thanks to Dr. James Murie, Mr. Harold L. Barnard, M.B., F.R.C.S., Mr. George Abbott, M.R.C.S., Mr. Frederick Meeson, Architect, and Mr. W. Whitaker, F. R.S.

The small sketch map which accompanies this pamphlet may serve as a guide to the more detailed information contained in the larger maps of the Geological Survey. A full index has been added in which the heights are given of all places mentioned on the map or referred to in the text.

ARCH. GEIKIE.
Director-General.

Geological Survey Office,
28, Jermyn Street, London, S.W.
6th November, 1897.

UNIVERSITY OF CALIFORNIA SANTA BARBARA

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WITH ESPECIAL REFERENCE TO LONDON AND ITS NEIGHBOURHOOD.

CHAPTER I.

INTRODUCTION.

THE problem of choosing a place of residence exercises the minds of many whose homes are not fixed by the bonds of inheritance nor by the necessities of their mode of livelihood; it also concerns the less favoured individuals who are obliged to seek abode within a certain limit in or near some large town or city. Apart from other circumstances that affect life in town and country, it has become desirable, and in many instances essential, that attention be paid to the sanitary conditions which depend on the nature of the subsoil; and increasing importance is now attached to the subject by Architects and Physicians.

Around London, for example, the idea has become widespread that a site on chalk, on gravel or sand, or on some other dry and porous material is to be preferred to one on clay. Nevertheless, a good deal of misapprehension exists with regard to the advantages of gravel as a subsoil, and of the disadvantages of clay; in certain circumstances either may be good, or both may be bad as sites for houses.

The object of the present little work is therefore to supply such information as may be needed by those who are compelled to be careful in choosing their place of residence. All house-hunters indeed would do well to consider the general sanitary conditions connected with proposed sites; and to bear in mind that a healthy habitation depends on several considerations, apart from the nature of the subsoil. There are the elevation of the ground and other local circumstances, and more important still the construction of the house itself, its damp-proof basement, its airy and sunny position, and the system of drainage. Lastly, the water-supply is a question of vital importance.

London and its Neighbourhood.

London being the chief centre of attraction to Britons, it is desirable to describe in some detail the nature of the various subsoils which occur over the large area embraced by the city and its suburbs.

In the district known at the General Register Office as "Greater London," there is an area of 701 square miles, including "all parishes wholly comprised within a circle of 15 miles from Charing Cross, and all other parishes of which any part is included within a circle of 12 miles radius from the same centre." * Barnet on the north, Barking on the east, Croydon on the south, and Staines and Uxbridge on the west, come within the range of Greater London. While the influence of the metropolis pervades the entire area, some portions of it may still be regarded as semi-rural, for the thickly populated region, known as the County of London, extends over no more than 121 square miles. The County includes Hampstead, Islington, and Hackney on the north; Bow, Poplar, and Plumstead on the east; Eltham, Sydenham, Streatham and Tooting on the south; and Roehampton, Putney, Fulham, Hammersmith and Paddington on the west.

This nucleus of Greater London requires distinct treatment with regard to the sanitary conditions of its subsoils. In the "Outer Ring," which includes the large area outside the home-county, nature still exercises a good deal of sway. In the County itself, which may be spoken of simply as London, nearly all is changed. Some forty or more villages have been merged in one vast concourse of buildings; and it may be said that few areas are so little influenced by the *original* soil and subsoil, as this densely populated region.

The streams no longer flow above ground, but the rainfall, whose access to the soil and subsoil is arrested over so much of the area, is diverted, together with the ancient brooks, into subterranean channels or sewers. The sewage consists of the mass of the water-supply and rainfall over the metropolitan area, with refuse from the streets, houses, and manufactories. After treatment, this sewage is discharged into the Thames from the northern outfall at Beckton, in Barking Reach, and from the southern outfall at Crossness, about a mile and a quarter lower down on the other side of the river. The clarified sewage, a fairly clean "effluent," amounts to more than 200,000,000 gallons a day; and thus these outfall streams probably constitute the most important tributaries of the river near London.†

Over extensive areas, the subsoils have been dug up for "ballast" or gravel, as at Kensington, and for brickearth as at Highbury,

* Report of the Royal Commission appointed to inquire into the Water Supply of the Metropolis, 1893, p. 5.

† See Prof. F. Clowes, *Nature*, Dec. 20, 1900, p. 190.

and the pits have been filled with rubbish. Elsewhere new buildings have been erected on the crumbling remains of old houses, so that over a great part of London the immediate foundation is what is known as "Made Ground" or "Made Earth." At the Stamford Bridge Athletic Grounds much gravel has been removed, and the excavations have been filled with London Clay from Tube-railway borings. It is understood that buildings may not be erected on this site until a period of ten years has elapsed.

So much of the ground in a large city, being artificially modified, it is evident that geological maps lose much of their local value in reference to sites suitable for houses. Such a map of London, for instance, may depict an area of gravel or of loam (sandy clay or brickearth), while on the site of a particular row of buildings there may have been a gravel-pit or a brickyard, and the excavation may have been filled with rubbish. Thus, a house standing on some 6 or 8 feet of modern "Made Ground" over gravel may be no better and may be a good deal worse, as regards its sanitary conditions, than one situated on a similar thickness of ancient "Made Ground" over clay. A house built directly on clean London Clay, with a good cemented basement, may be decidedly better.

Geological Considerations.

Various earths or strata appear at or near the surface in different parts of the area, and these are represented on the map accompanying this work. The *soil*, which comprises the superficial layer of turf or mould, and the more or less disturbed earth of the cultivated surface, is not distinguished. Practically it covers the entire area, except where artificially removed.

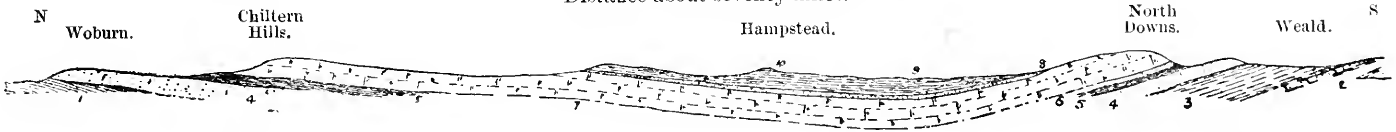
The *subsoil* is the earth or geological formation which lies directly beneath the soil. In the area indicated by the map, it may consist of gravel, sand, sandstone, loam, clay, silt (sandy mud), marl (calcareous clay), peat, or chalk. Several distinct groups of gravel and sand, sand and sandstone, loam, clay, &c., are met with. Belonging to different periods in the earth's history they are known individually or collectively under such names as the Bagshot Beds, London Clay, Gault, &c. It may, however, be taken for granted that the character of each tract of clayey land, apart from other circumstances, is practically the same, whether composed of Weald Clay, Gault, or London Clay; the same may be said of sandy areas, whether formed of Bagshot Sand or Thanet Sand; and of gravelly areas whether formed of Blackheath Beds, Glacial Drift, or Valley Gravel. The subsoils will therefore be treated with regard to their natural characters, and the text will be arranged in accordance with these rather than with geological age or sequence. A few remarks on the structure of the London area may, however, serve to render the subject more intelligible.

London is situated in what is termed in geological language a "basin"—the "London Basin." The solid foundation at some depth underground (150 to 300 feet, and less in places) is composed of the Chalk, a formation here about 650 feet in thickness. This it is which constitutes the so-called basin, whose broad rim comes to the surface in the Chiltern Hills on the north and north-west, and in the North Downs on the south. (See Fig. 1.) The basin is in reality an irregular and broken one, for the framework of eastern England comprises only the western portion of it, the eastern part being covered by the German Ocean; while to the south-east of London a part of the basin is fractured, as the Chalk, through disturbance of the strata, or "faulting," appears at the surface in the midst of the area near Charlton and Lewisham. The general structure of the Basin is shown in the accompanying section drawn from north to south across London (Fig. 1).

Beneath the Chalk there occur in succession the Upper Greensand, Gault Clay, and Lower Greensand; but while the Gault is everywhere present beneath the London Basin, neither Upper nor Lower Greensand is persistent. These formations outcrop on the southern side of the Basin, appearing from below the Chalk escarpment of the North Downs, and they are succeeded by the Weald Clay and Hastings Beds, which form the great area known as the Weald in Surrey, Kent, and Sussex. On the northern side of the Basin the Upper Greensand (in places) and the Gault occur below the Chalk escarpment of the Chiltern Hills beyond Princes Risborough, Wendover, Tring, Dunstable, Hitchin, and Baldock. In parts of this area far north-west and north of London, the Lower Greensand appears beneath the Gault, extending in outlying patches at Stone and Dinton, near Aylesbury, and in a broad tract from Leighton Buzzard to Woburn, Aspley Guise, Ampthill, Shefford, Biggleswade, and Potton. Aylesbury itself is situated on the limestones and sands of the Portland Beds which overlie the Kimeridge Clay. In the Woburn area the Lower Greensand rests on the Oxford Clay, a stiff clay of considerable thickness which does not elsewhere appear in the district to which attention is now directed. (Fig. 1.) These older strata form part of the framework of south-eastern England outside the rim of the London Basin. Together with the Chalk they are grouped with the Secondary formations.

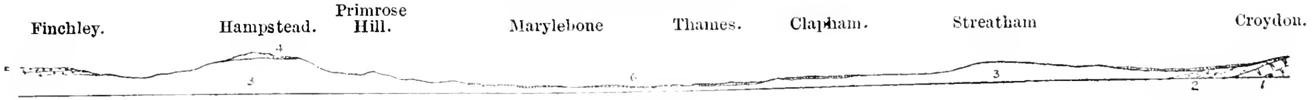
The hollow of the London Basin is filled by a series of sedimentary formations, which are classed as Tertiary. Conforming generally to the gentle fold into which the Chalk has been bent (see Fig. 1), they consist of a lowermost group of sands, pebble-beds, and clays (8), known as the "Lower London Tertiaries," and divided into the Thanet Sand, Woolwich and Reading Beds, and Blackheath Beds; overlain by a great mass of clay, termed the London Clay (9); and followed by a group of sands with thin

FIG 1.—*Section across the London Basin.*
Distance about seventy miles.



Alluvium and Valley gravel (not shown).
10 Bagshot Sand.
9. London Clay
8. Lower London Tertiaries.
7. Chalk.
6. Upper Greensand.
5. Gault.
4. Lower Greensand.
3. Weald Clay.
2. Hastings Beds
1. Oxford Clay.

FIG. 2.—*Section across London from Finchley to Croydon.*
Distance sixteen miles.



6. Valley gravel and loam.
5. Boulder-clay with underlying sand and gravel.
4. Bagshot Sand.
3. London Clay.
2. Lower London Tertiaries. Blackheath Beds. Woolwich and Reading Beds. Thanet Sand.
1. Chalk.

clayey bands, known as the Bagshot Sand (10), which in London itself caps the higher grounds of Hampstead and Highgate. Of these strata the London Clay occupies the most extensive area, the thinner group below (8) appearing at the surface over a comparatively narrow belt. All, however, occur in regular sequence.

Overlying many of these strata, and, indeed, resting indifferently on any portions of them, there are other gravels and sands, loams, and clays, classed as Quaternary. They do not partake of the bend to which the Tertiary strata beneath have been subjected ; but the curve (as shown in Fig. 1) is too slight to be observed, save in a diagram where the vertical scale is exaggerated. These newer deposits comprise local accumulations of clay-with-flints and loam on the Chalk tracts ; also of chalky and stony clay (Boulder-clay) as at Muswell Hill and Finchley ; and high-level gravel and sand, as at Wimbledon, Stanmore, and Barnet. (See Fig. 2.) They include the more extensive sheets of gravel and loam along the Thames valley : deposits which were accumulated and distributed by the river in ancient times. They comprise also the more modern strip of marshland or Alluvium, which immediately fringes the river over small areas above London, and over broader tracts in southern Essex and northern Kent.

These newer deposits are scattered somewhat promiscuously over the abraded surfaces of the Bagshot Beds and older strata. They have a sequence of their own in point of time, but this is not maintained, as in the case of the older deposits, by the regular succession at any one locality of all the deposits, although two or more of them may in places be in sequence. They lie at various levels and appear in different localities. Some have been formed only over limited tracts, like the Alluvium, certain of the gravels, and the clay-with-flints ; others have formerly spread over much wider areas ; and all, with the exception of the Alluvium, have since suffered more or less destruction or erosion, so that in some localities only scattered patches of gravel or Boulder-clay now remain of former extensive sheets.

Arranged in the order of their natural sequence or period of formation, the soils and subsoils are as follows :—

	Geological Formations and Soils.	Characters.
	Natural Soil and Made Ground -	Superficial covering of *mould*, and disturbed ground.
Quaternary.	Alluvium - - - -	*Silt, marl, peat, clay,* and *gravel*
	Valley or River Gravel and Brickearth	*Gravel* and *loam.*
	Clay-with-flints (of varying age)	*Clay, loam,* and *flints.*
	Glacial and Plateau Drift - - -	*Boulder-clay, loam, gravel* and *sand.*
Tertiary.	Barton Sand (" Upper Bagshot Beds ")	*Sands.*
	Bracklesham Beds - - - -	*Clays and sands.*
	Bagshot Sand ("Lower Bagshot Beds")	*Sands and loam ; with local pebble-beds.*

Tertiary.	London Clay	*Clay.*
	Blackheath Beds	*Gravel* and *sand.*
	Woolwich and Reading Beds	*Clay, shelly marl, sand,* and *gravel.*
	Thanet Sand	*Sand.*
Secondary.	Chalk	Soft white *limestone*, with bands and nodules of *flint*; and *marl.*
	Upper Greensand	*Sandstone* and *sand.*
	Gault	*Clay.*
	Lower Greensand	*Sand* and *sandstone*, with *limestone, chert*, and *clay.*
	Weald Clay	*Clay.*
	Hastings Beds	*Sand, sandstone*, and *clay.*

Geological Maps and Models.

The little map which accompanies this work will be useful as an index to the general distribution of the subsoils in the area around London.

The Geological Survey has also published a colour-printed one-inch map of the London District in four sheets:—

No. 1 includes Rickmansworth, Barnet, Uxbridge, and N.W. London.
No. 2 includes Enfield, part of Brentwood, Upminster, and N.E. London.
No. 3 includes Staines, Chertsey, Sutton, and S.W. London.
[In this map the areas coloured Woolwich and Reading Beds beyond the main outcrop at Sutton, should have been coloured London Clay.]
No. 4 includes Purfleet, Farningham, Croydon, and S.E. London.

Maps on the scale of six inches to a mile are, however, necessary for all practical purposes. All the recent work of the Geological Survey has been carried out on these large-scale maps, MS. copies of which are preserved at the Office; but at present only a portion of London and of the country around has been surveyed geologically on a scale larger than that of one inch to a mile.

The following is a list of the MS. copies of Geological six-inch maps of the London District (see Index-map, p. 70):—

Middlesex.

2 S.W. Enfield Chase.
5 N.E. Bushey, Herts.
S.W. Pinner Hill.
S.E. Stanmore.
6 S.W. Edgware.
7 N.E. (1 L.) Enfield.
S.W. Southgate.
S.E. Edmonton.
9 N.E. Harefield.
S.E. Ickenham.
10 N.W. Pinner.
N.E. Wealdstone.
S.E. Harrow.
11 N.W. (2 L.) Kingsbury.
N.E. Hendon and Finchley.
S.W. Neasden and Wembley.
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12 S.E. (3 L.) Stoke Newington.
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S.E. West Drayton.
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S.E. Ealing and Hanwell.
16 N.W. (6 L.) Willesden.
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S.W. Acton.
S.E. Kensington.
18 N.E. (8 L.) Bow.
19 N.W. Colnbrook End.
N.E. Harmondsworth.
S.W. Wyrardisbury, Bucks.
S.E. Stanwell.
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N.E. Brentford, Hounslow.
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N.E. Staines, Laleham.
S.E. Shepperton.
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1 S.E. (9 L.) Kew.
2 S.W. (10 L.) Mortlake.
S.E. Battersea.
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S.E. Kingston-on-Thames.
7 N.W. Putney Heath.
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S.E. Romford.
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S.W. Barking Level.
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75 N.W. Upminster.
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82 N.E. Rainham Marsh.
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BUCKS.

53 N.E. Fulmer.
S.E. Iver.
56 N.E. Langley.

LONDON.

4 N.W. Woodford.
S.W. Wanstead.
S.E. Ilford.
8 N.E. Barking.

Those marked L. are London County maps.

Reference may here be made to the Geological Model of London (scale, six inches to a mile) prepared under the superintendence of Mr. W. Whitaker and placed in the Museum of Practical Geology. A smaller Geological Model of London and Suburbs, on the scale of one inch to a mile, prepared by Mr. J. B. Jordan, and published by Mr. E. Stanford, is also exhibited in the Museum.

Further particulars of the geology of the district will be found in Mr. Whitaker's "Guide to the Geology of London," ed. 6, 1901, price 1s.; and in his "Geology of London and of Part of the Thames Valley," 2 vols., 1889. price 11s., issued by the *Geological Survey.*

Separate Memoirs have also been issued on "The Water Supply of Berkshire from Underground Sources," by the late J. H. Blake, with contributions by Mr. Whitaker, 1902, price 3s.; and on "The Water Supply of Sussex from Underground Sources," by Mr. Whitaker and Mr. C. Reid, 1899, price 3s.

CHAPTER II.

SOILS AND SUBSOILS OF LONDON AND ITS NEIGHBOURHOOD.

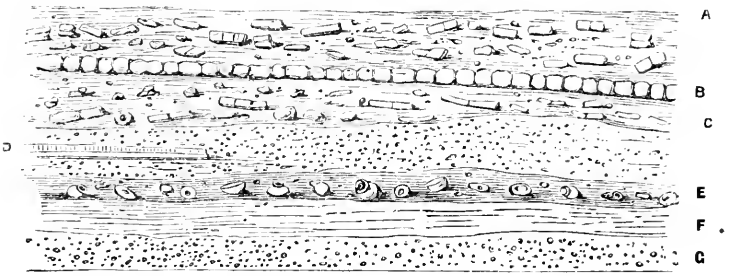
SOILS.

Made Ground.

The surface-soil of London, and also of many other large cities and towns, is a mixture of mould, gravel, or clay, with débris of ancient buildings and rubbish. Much of this has been upturned over and over again, so that it comprises an accumulation of brick-bats, fragments of crockery, and what not, commingled with relics of the soil and subsoil. In a few localities in London it has accumulated steadily, or at irregular intervals, at the rate of from 6 inches to 1 foot a century. Portions of the "Made Ground" are thus of ancient date, and in these undisturbed areas it has preserved trophies of the Roman occupation, of the Great Fire, and other interesting episodes. (See Fig. 3.)

FIG. 3.—*Section in Cannon Street.*

(W. Chaffers.)*



Made Ground 9ft.
- A. Level of the street.
- B. Roadway before the Great Fire of London, in 1666.
- C. Earth in which Norman and Early English Pottery is found.
- D. Roman tesselated pavement.
- E. Black soil in which red lustrous (Samian) and other Roman ware is found.

Valley Drift. F. Loam. G. Gravel. 3 ft.

* F. W. Rudler's "Handbook to Collection of British Pottery and Porcelain," 1893, p. 67; Whitaker, "Geology of London," *Geol. Survey*, vol. ii, 1889, p. 324. See also A. Tylor, *Archæologia*, vol. xlviii., 1885, p. 222.

Made Ground may be from a foot to about 25 feet in thickness, the greater thicknesses being here and there due to the in-filling of old pits. Excavations at London Wall showed the following section :*—

	Feet.
Made ground - - - - - - - - - - -	about 8
Dark carbonaceous clay with freshwater shells and traces of vivianite - - - - - - - - - -	about 10
Thin bed of broken bones - - - - - - -	—
Gravel - - - - - - - - - - -	about 10
London Clay	

At the Bank of England there were 22 feet of Made Ground, resting on four feet of gravel, over London Clay. In describing the excavations on the site of the New Law Courts, Mr. W. H. Hudleston and Mr. F. G. Hilton Price drew attention to the extreme irregularity in the junction between the Made Soil (brick-rubbish, etc.), and the underlying gravels: thus "Many an old foundation may be seen projecting like a promontory into the subjacent sandy gravels, and, where these thin out, into the London Clay itself. The numerous old wells also tend to confusion in this respect."† At the corner of St. James' Square and King Street, the Made Ground was 10 feet thick, and sand was proved to a depth of 16 feet beneath it.

Such artificial "Soil" of varying character and thickness, no doubt extends over the whole of old London. Mr. Whitaker has remarked that Belgravia is probably in great part built on ground of this nature, otherwise it would be lower and damper.

In itself Made Ground is not always an unsatisfactory foundation for a house. Much of it, as stated, is of ancient date. Moreover good material may artifically be brought to level an irregular tract. The serious matter is that in these enlightened days it has been possible for houses to be erected on pits in which all kinds of rubbish, with decaying vegetable and animal matter, had recently been shot. As Sir Douglas Galton remarked, "What then can be more dangerous, what more wicked, than the everyday proceedings in the metropolis and elsewhere, of those persons who purchase a building site, who extract from it the healthy clean gravel and sand which it contains, allow the hole to be filled with rubbish, and then proceed to build upon it?"‡ It is well known that injurious emanations come from an impure soil or subsoil, and may rise into a house; so that on such an unwholesome foundation it is absolutely necessary that the basement be securely cemented. The law should now prevent any further building of houses on polluted sites.

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* E. A. Martin, "Science Gossip," ser. 2., vii., 1901, p. 319.

† *Proc Geol. Assoc.*, vol. iii., 1872, p. 44.

‡ *Trans. Sanit. Inst.*, vol. i., 1880, 120.

Natural Soil.

The natural soil is of varied composition, being primarily derived from the subsoil, which may be regarded as the weathered portion of the underlying hard or soft strata. With the decomposed mineral ingredients of the subsoil is mingled more or less decayed animal and vegetable matter; while the whole soil-layer has been largely re-constituted by the action of earth-worms and micro-organisms, by plant-growth, and processes of cultivation. To the work of worms, as pointed out by Darwin, is due the fine surface-layer of *mould*, which is rich in vegetable matter; and as stated by Mr. A. D. Hall, the term *humus* "is applied to the black or dark brown material of vegetable origin which gives to surface soil its characteristic darker colour as compared with the subsoil. It is essentially a product of bacterial action."* Wind-drifted material has also to some extent modified the constituents of soil.

As a rule, the natural soil is too thin to have any particular effect on the sanitary conditions of a site, although in places it may be as much as 3 feet or more in thickness. It is thicker on the lower slopes of hills and in valleys, owing to its downwash by rain from the higher grounds. It is usually thicker also on the gravelly, sandy and loamy areas than on the stiff clays or on the Chalk. †

With regard to micro-organisms (bacteria), which are found in soils, it is satisfactory to know that "the dangerous microbes are in a hopeless minority in comparison with the number of those which are continually performing varied and most useful functions in the economy of nature." Moreover the surface-layers of the soil harbour the vast majority of the bacteria; they lessen in number in the deeper layers, and few or none are to be met with in the subsoil at a depth of 8 or 10 feet. Their number lessens when the surface-soil is moist, and increases as it dries.‡ Certain pathogenic organisms, however, appear to flourish at a depth of 4 feet in the soil, when its temperature is above 56°.§

SUBSOILS.

Alluvium or Marshland.

The low-lying tracts that immediately border the Thames and its tributaries, and that fringe the lower courses of most rivers, should be regarded as essentially the property of the river.

* "The Soil," 1903, pp. 14, 41. See also C. Reid, "Dust and Soils," *Geol. Mag.* 1884, p. 165.

† For remarks on the influence of the colour of soil on temperature, *see* Dr. H. R. Mill, *Trans. Sanit. Inst.*, vol. xv., 1895, p. 174; H. A. Roechling, "Geology in Relation to Health," *Trans. Leicester Lit. and Phil. Soc.*, vol. v., 1900, p. 347.

‡ Dr. Allan Macfadyen (Discourse at Royal Inst.) *Nature*, Feb. 7th, 1901, p. 359.

§ Dr. S. M. Copeman, *Trans. Sanit. Inst.*, vol. xvii., 1897, p. 37. Bacteria are microscopic forms of plant-life, and they include rod or chain-like forms (bacilli), and grains (cocci).

Originally marshlands, they sometimes remain so, and at any rate they are liable to be flooded when the river is so swollen as to overflow its natural banks. Artificial ramparts may preserve these tracts as meadow-lands, but they are to be avoided as sites for residences; and it is noteworthy that they were not chosen by the early settlers. Composed of silt and clay with peat and occasional layers of marl or gravel, these beds vary in thickness from 5 to 40 feet, and form a damp and unreliable foundation. Gravel usually underlies the Alluvium, and this is often waterlogged, so that if the river be in flood and the Alluvium be thin or porous, water may rise in the cellars of houses built upon such low-lying ground.

Basements of houses erected on river-flats are in any case liable to be damp, and their construction in such situations is undesirable: if, however, it cannot be avoided, the houses should be constructed with impervious walls and floors. Permanent injury may be done to buildings if in more open country such sites are chosen, and the river occasionally asserts its rights by flooding the tract. In wet weather sheets of water may cover areas of Alluvium for some length of time.

Fortunately there are but small areas of Alluvium in the heart of London; there are tracts at Walbrook and Pimlico, and also at Lambeth, Bermondsey, Rotherhithe, Deptford, and the Isle of Dogs. After long-continued rains, and with an East-North-East wind accompanied by high-tide, the Thames sometimes rises so as to flood the lowest parts of Wapping, Deptford and Rotherhithe, of Southwark, Lambeth, and Vauxhall.

In consequence of a gale which changed during the night of November 28th, 1897, from South-West to North-West, there was an immense influx of water into the Thames from the North Sea, the river rising 6 feet higher than usual. The wharves at Woolwich Arsenal and the Royal Dockyard were flooded, so also were Tilbury Marshes and the lower part of Grays. On the following evening the river rose 3 or 4 inches above the level of the Embankment footway near the Temple.*

In certain localities a protective covering of Made Ground, 4 to 6 feet thick, renders the old marshland habitable, as at Pimlico. There the Alluvium itself is from 6 to 30 feet in thickness, the deeper portion being nearer the river. At the Grosvenor Hotel the following superficial strata were proved :—

	Ft.	In.
Made ground - -	4	0
Mud - -	4	9
Peat - - - -	3	3
Clay - - - -	2	0
Peat - - - -	1	0
Sand and gravel - -	9	0
	24	0

* *Daily News*, December 30th, 1897.

Westminster is thus situated on old marshland, part of the area being formerly the island known as Thorney.*

A tract of Alluvium occurs along the Colne valley from Watford, widening out through the lower part of Rickmansworth, and extending by Uxbridge to Staines. On Staines Moor and by Runnymede (Runemede) the ground contains much peat, and has been subject to floods. Below Staines the high road to Chertsey and the Alluvium onwards to the tributary valley of the Wey, likewise the low grounds bordering the Mole, between Hersham and Thames Ditton, are liable to floods.

Along the Brent valley between Greenford and Hanwell, the Alluvium consists largely of re-deposited London clay, with seams of gravel, and the tract of flat meadow-land is subject to floods.

There is a broad tract of Alluvium along the Lea valley, forming the marshes of Enfield, Tottenham, Walthamstow, Hackney, and West Ham; and a similar tract extends along the northern side of the Thames in the Levels of Plaistow, East Ham, and Barking, and the marshes of Dagenham, Rainham, Grays and Tilbury. Severe floods sometimes occur in the Lea valley, and cause injury to the market-gardens in the low grounds. The Walthamstow, Hackney and Stratford marshes are occasionally covered by two or three feet of water, and flood-waters may occupy the flats by Waltham Cross, Cheshunt, and Chingford. The valley of the Roding at Ilford is also liable to floods.

On the southern side of the river there are the marshes of Greenwich and Plumstead, areas which are embanked; but the basements of houses at Lower Charlton and elsewhere along their borders have at rare intervals been flooded.

In places these low-lying tracts, some of which are below the level of high-water mark, have been utilized in the construction of Docks. Elsewhere gas-works, chemical factories, candle and soap-works have been established. There are indeed growing populations on the East Ham and Plaistow Levels, as at Canning Town, Beckton, Silvertown, and North Woolwich; but while the necessities of livelihood or calling require residence in them, such areas are in general undesirable, though I have been assured that Beckton is not unhealthy. Possibly the disinfecting influence of the gas-works may contribute to the salubrity, while the currents of air that follow the course of the river are no doubt beneficial.

Crossness again, with its main drainage-works, is not a locality which one would naturally choose as a residence, but the best care is taken of those who are obliged to seek a habitation near the works. (See Fig. 4.)

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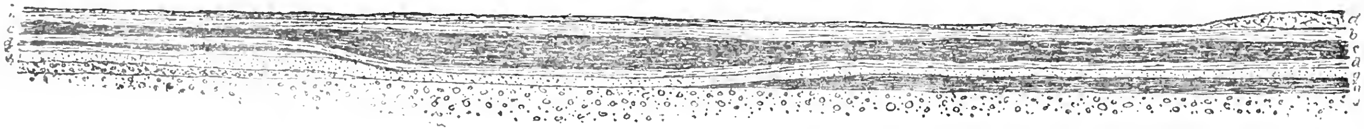
* See W. J. Loftie, "History of London," 1883, vol. ii., p. 34.

FIG. 4.—*Section at Crossness.* (Metrop. Board of Works.)*



Scale 88 feet to an inch.

Alluvium { *a.* Soil. *b.* Silt. *c.* Peat. *d.* Clay. *e.* Peat.

f. Clay.
g. Sand and clay.
h. Peat and clay.
i. Gravel.

FIG. 5.—*Section across the valley of the Wandle.* (W. Whitaker.)†

Longitudinal scale: an inch = 1 mile.

a. Alluvium. *b.* Gravel. *c.* Bagshot Sand. *d.* London Clay.

* Whitaker, "Geology of London," vol. i., fig. 98, p. 466.

† *Ibid.* voi. i., fig. 86, p. 428.

One of the most serious objections to any large population on alluvial grounds, as pointed out to me by Mr. F. J. Bennett, is the difficulty of introducing any effective system of house-drainage, owing to the want of all to carry away the sewage. This, however, applies to low-lying ground in general. Another difficulty may be the water-supply, as at Rainham Ferry, on the Essex marshes, where in the absence of a deep well "the inhabitants are entirely dependent for their supply on rain water and on condensed water from the manufactories."*

Gravel, Sand and Sandstone.

Valley Gravel.

The Valley gravel and loam (brickearth) are ancient alluvial deposits of the Thames and its tributaries, occupying tracts above the level of the marshland, and indeed rising to elevations of 140 to 180 feet and more along the Colne valley, at Denham and south-west of Rickmansworth; and to about 150 feet at Highbury. The loam (see p. 29) occurs irregularly in and over the gravel.

The gravel is most largely composed of flint in the form of subangular stones and pebbles, together with quartz and quartzite pebbles. It contains much sand in places, and occasionally peaty layers occur. Both sand and gravel are locally blackened by oxide of manganese.

The greater part of old London and the villages now incorporated in modern London were built on the valley gravel. Naturally these tracts include some of the better residential sites in London and the vicinity; but it must be remembered that they vary a good deal in elevation, some being but a few feet above the Alluvium, and that the sanitary condition of the ground largely depends on the situation and thickness of the gravel. In low-lying areas especially, where there are broad tracts of gravel, the subsoil is likely to contain much water, and the basements of houses are apt to be damp. This is the case sometimes at higher elevations where the gravel is thin or where it lies in a sort of basin, and where living-rooms are constructed partially beneath the surface.

The larger portion of the broad valley of the Thames from Great Marlow to Maidenhead and Taplow, Windsor, Eton, Colnbrook, Staines and Chertsey, eastwards to Hounslow, Twickenham and Teddington, is occupied by valley gravel and sand, with here and there areas of loam. Mixed areas of gravel and loam occur in the vicinity of Brentford, Hanwell, Ealing, Acton, and Gunnersbury. Moreover a thin loamy covering which extends over portions of the gravel tracts, has exercised an important and beneficial influence on the soil. This district has in consequence been long celebrated

* Report to Local Government Board, by E. Evans, 1894.

for fruit and vegetables, although many a famous market-garden or nursery-ground has now vanished from neighbourhoods such as Chelsea and Hammersmith, where in old times they flourished.*

It has been remarked that the prosperity of London market-gardens is due partly to the proximity of a market, partly to the large amount of stable-manure that could be readily obtained.† With the introduction of motor-vehicles the lack of manure is already being experienced.

At the Mount and Castlebar Hill, Ealing, there are thin patches of gravel resting on London Clay, but the ground is essentially clayey, although here and there it is lightened by the former presence of gravel and sand, of which relics are preserved in the soil.‡

On the southern side of the river, Mitcham and other localities have also furnished market-gardens, and grounds formerly celebrated for the cultivation of lavender, camomile, peppermint, and other medical herbs. The cultivation of lavender, &c., is now carried on further south, mainly on chalk tracts.

Among the residential districts south of the Thames, Egham, Chertsey, Addlestone, and Byfleet, Walton-on-Thames, Hersham, Molesey, and Thames Ditton are situated on valley gravel, so also are the lower parts of Richmond, Kew, Mortlake, and Putney. Near the Thames in these, as in other similar localities, the gravel is especially liable to contain a good deal of subsoil-water, and basements of houses may be damp. This would be the case after long-continued rain, when, as sometimes happens, the river rises so high that the islands near Twickenham, Richmond, and Isleworth are covered with water, while the low grounds bordering the river from Kingston to Barnes and Chiswick may be inundated. Under such conditions cellars are sometimes partially flooded, for the ground-water naturally rises to the level of the swollen river. When the Thames is in flood the low grounds extending from Eton by Datchet, Wyrardisbury (Wraysbury), and Egham to Staines and Chertsey are not unfrequently under water. (See p. 13.) At Windsor on January 23rd, 1899, the river was 2 feet 8 inches above its summer-level.

Further east much of the valley gravel occurs in straggling masses or isolated tracts on the London Clay, so that Roehampton, Putney, Wandsworth, Clapham, Brixton, Tooting, Merton and Raynes Park, Croydon and also Lewisham are partly on gravel and partly on the clay or lower Tertiary strata, the old villages having outgrown the limits of the gravel areas on which they were originally fixed. On the higher and more isolated

* There remain the Chelsea Botanic Gardens, now administered for the promotion of the study of Botany, and formerly known as "The Physick Garden" of the Society of Apothecaries.

† G. V. Poore, "Essays on Rural Hygiene," 1893, p. 317.

‡ See J. Allen Brown, *Quart. Journ. Geol. Soc.*, vol. xlii. p. 192.

tracts of gravel the sites are drier than in the lower grounds, as the subsoil water more readily escapes in the form of springs. The lower parts of Lewisham have been flooded after long-continued rain, and so also have similar tracts at Mitcham and Merton.

North of the Thames the valley gravel extends beneath the greater part of old London, through Stepney, Bow and Hackney, on the east side of the Lea valley from Stratford to West Ham, Barking, Romford, Dagenham and Rainham; while north-eastwards it stretches to Leyton and Wanstead, and over parts of Walthamstow. In the semi-rural portions of this region there are market-gardens. The lower grounds of Romford have at times suffered from the flooding of the river Rom, which flows through the town.

On the western side of the Lea valley there is a belt of valley gravel which occupies the area from Cheshunt by Waltham Cross and Enfield Lock to Ponders End.

Islington, with Canonbury, Barnsbury, and parts of Highbury (near the Church) lie on gravel; so also do Bloomsbury, Marylebone, Paddington, Kensington (the older portions), Brompton, and Chelsea. Kensington gravel-pit was situated on the borders of Notting Hill, north-west of Kensington Gardens; similar gravel may now be seen in the railway-cutting between High Street and Gloucester Road Stations.

The gravel and sand often contain much water, and this afforded in old times a supply to the villages now incorporated in London. In excavations for the new buildings of the Victoria and Albert Museum, about 1000 gallons of water an hour were pumped from the gravel, which was excavated to a depth of 15 feet beneath 5 feet of made soil. During drainage-operations at Highbury, east of Highbury Park and Grove, much water was encountered in the gravel. This ground-water is a cause of dampness to some underground breakfast-rooms. It has been suggested that water from the gravel might be pumped for use in watering roads, &c., but there would be some danger of weakening the foundations of buildings if such a proceeding were generally adopted.

The valley gravels and associated loams are from five to about forty feet in thickness. As instances of the variable character of the subsoils, the following sections may be noted * (See also p. 30) :—

Marylebone Road.	Feet.	*West Ham.*	Feet.
Made ground -	9	Made ground -	$4\frac{1}{2}$
Loamy gravel -	8	Gravel and clay -	$2\frac{1}{2}$
Loam - - -	8	Gravel - -	$10\frac{1}{2}$
Gravel - -	$8\frac{1}{2}$		
	$33\frac{1}{2}$		$17\frac{1}{2}$

* *See* Whitaker, "Geology of London," 2 vols., 1889.

Fulham.

	Feet.
Made ground	3½
Fine sand	10½
Sand and gravel	18½
	31½

Peckham.

	Feet.
Gravel	3
Loam and sand	14
Gravel	3
	20

On the southern side of the North Downs, tracts of valley gravel border the Wey and its tributaries at Godalming, Shalford, Guildford, and Wonersh; the Darent between Westerham, Sundridge and Otford; and the Medway from Maidstone to Leybourne, Aylesford, and Snodland.

To the north of the Downs at Millmead, Guildford, the lower portions of houses have been flooded, and further along the course of the Wey, at Woking village and also at Send, the effects of floods are occasionally experienced.

Gravel of Higher Grounds and Plateau Drift.

Beds of gravel and sand, occupying as a rule higher levels than the valley gravel, occur in many tracts of the country around London, on the clay-areas of Buckinghamshire, Middlesex, Hertfordshire, Essex, Kent and Surrey. Other and more extensive tracts of gravel occur at various elevations on the Chalk between St. Albans and Beaconsfield, and they furnish sites as dry probably as any to be found in the area under consideration.

These gravels are from a few feet to about 25 feet in thickness, and rarely as much as fifty feet. They vary in character from pebble-gravel or shingle, largely made up of flint and small quartz pebbles, to coarse sub-angular gravel and sand, containing, in addition to flint and quartz, many pebbles of quartzite and other stones.

On the clayey area there are patches of gravel in the higher parts of Richmond Park at Kingston Hill, Wimbledon Common and Putney Heath, at Shooter's Hill, over parts of Woodford, Chigwell, Buckhurst Hill, High Beech, and the higher grounds of Epping Forest, near Epping. Again, there are tracts of gravel and sand at Southgate, Colney Hatch, Friern Barnet, Whetstone, Totteridge, High Barnet, Monken Hadley, Ridge, Shenley, Potter's Bar, and Northaw, at Finchley, Hendon, Stanmore and Bushey Heath, Pinner Hill, Oxhey Wood, Moor Park, Horsendon Hill, Harefield and Hillingdon. Other patches of gravel lie to the south-west between Denham and Fulmer, on Fulmer and Stoke Commons to the north of Stoke Poges, and at Beaconsfield.

It is worthy of note that these gravels have sometimes a clayey or loamy matrix, and may then be of a retentive nature. I was told by a gentleman who had taken a house situated on a gravel patch at Totteridge, that his gardener informed him the soil was

a "heavy clay." Nevertheless, in excavating for a water-tank, he had dug out several tons of pebbles! The gravel, in fact, consisted of a stiff sandy clay packed with pebbles.

There are thin patches of gravel at Dollis Hill, near Neasden, at Highwood Hill, and also at Mill Hill to the south of the King's Head Inn and to the east of Frith Manor House. Sprinklings of gravel occur elsewhere on the higher clay hills, serving to lighten the soil; moreover they are found here and there on slopes below the larger patches of gravel. This is notably the case on Stanmore Hill, and again near Brentwood and Warley.

At Hendon, as pointed out by Dr. Henry Hicks, there is a thick bed of brown clay intercalated in the gravels, and a similar band locally occurs at Finchley. These are re-assorted masses of brown London Clay, which have become incorporated with the gravel during its accumulation.

These plateau gravels form, as a rule, good residential sites, because the subsoil water is to a large extent drained off by springs on their margins. Moreover, they occupy breezy positions.

More extensive tracts of gravel and sand occur, as before-mentioned, on the Chalk in Hertfordshire and Buckinghamshire. These comprise certain areas at Hitchin, Stevenage, Welwyn, Hatfield, Sandridge, St. Albans, London Colney, Aldenham, Watford, Chipperfield, Sarratt, Chenies, Chorley Wood, Croxley Green, and the higher grounds above Rickmansworth, Chalfont St. Peter, and Chalfont St. Giles. Beds of loam and clay are here and there intercalated with the gravel and sand. So far as the subsoil is concerned the areas may be highly commended; they are pleasantly situated and picturesque, and only in a few localities where the gravel descends to low grounds bordering the Colne valley above Watford, would the sites be liable to damp. As the water in the underlying Chalk is largely drawn upon for drinking-purposes, it is most desirable that the sanitary arrangements in dwelling-houses be so constructed that no pollution of underground water is possible.

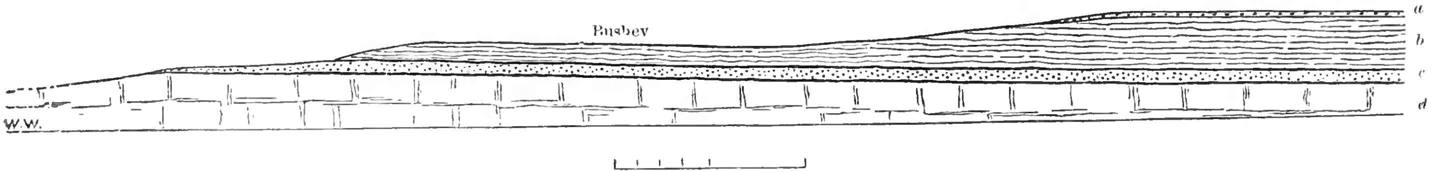
Here and there patches of gravel occur on the Bagshot Sands, as in Essex and Surrey, and the localities are noted in the descriptions of those sandy areas.

Blackheath Beds.

These are composed of gravel made up almost entirely of flint-pebbles in a sandy matrix, and often with beds of sand; but layers are occasionally cemented into a conglomerate. In thickness the beds vary from about 10 to 50 feet or more.

Their distribution is restricted. Appearing at the surface on the east of Croydon they extend over a considerable tract between Addington, West Wickham, and Beckenham; they occur at

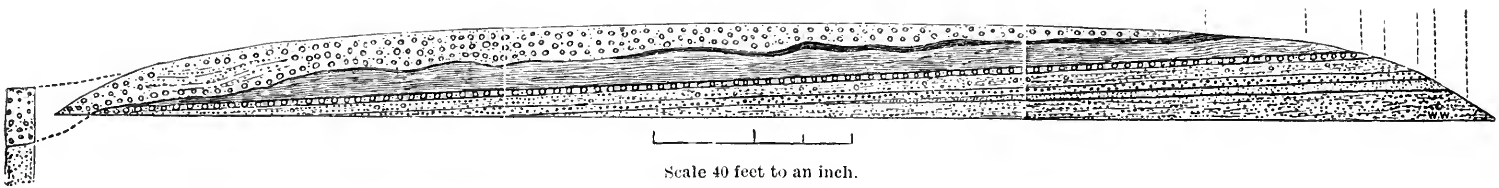
FIG. 6.—*Section across Bushey, near Watford, and Stanmore Heath.* (W. Whitaker.)*



Longitudinal Scale, 3 inches to a mile. Vertical scale, 880 feet to an inch.

a. Plateau gravel. *b.* London Clay. *c.* Reading Beds. *d.* Chalk.

FIG. 7.—*Cutting on the South-Eastern Railway at Chislehurst Station.* (W. Whitaker.)†



Scale 40 feet to an inch.

1. Pebble-gravel. Blackheath Beds.	2. Clay with shells. 3. Bluish and greenish-grey clay. 4. Sand with pebbles. 5. Green loam. 6. Green sand. } Woolwich Beds.	7. Whitish sand. 8. Buff sand. } Thanet Sand.

* "Geology of London," vol. i., fig. 105, p. 493.

† *Ibid.*, vol. i., fig. 26, p. 164.

Bromley, Hayes Common, Keston, Chislehurst, and Eltham, and again at Bexley Heath, East Wickham, Charlton and Blackheath. Outlying patches lie south of Caterham and at Worms Heath near Chelsham.

The soil above these deposits is dry and healthy, while the district is picturesque and admirably adapted for residences. The situation of these gravel-beds being more elevated than that of the valley gravels, they have in this respect a decided advantage. In short they may be considered to afford sites as good generally, from a sanitary point of view, as those on the large areas of the Bagshot Beds, and of the higher gravels on the Chalk of Hertfordshire and Buckinghamshire.

Barton Sand.

The higher elevations in the region of Bagshot Heath, Easthampstead Plain, Chobham Ridges and the Fox Hills, parts of Aldershot and Eversley Commons, comprise the Barton or "Upper Bagshot Sands," about 100 feet thick where fully developed. These beds are capped extensively by gravels which contain hard concretionary masses of sandstone, known as greywethers or Sarsen stones. Pirbright Common and the greater portion of the Necropolis at Brookwood are situated on the Sands. The region is for the most part wild and picturesque, comprising much heathland and many plantations of Scotch fir.

Bagshot Sand.

These strata, which take their name from Bagshot Heath in Surrey, and were formerly grouped as "Lower Bagshot Beds," are most largely composed of sands, with occasional thin seams of white pipeclay and pebbly layers. The sands are usually fine-grained and buff in colour, but greenish beds are occasionally met with. The beds are sometimes indurated into an iron-sandstone with or without pebbles.

To the north-east of London small tracts of Bagshot Sand form the hilly ground at High Beech, near Loughton, there covered irregularly by gravel. Between High Beech, Loughton, and Epping, the ground is mostly of a light and loamy nature, with here and there beds of sand and sprinklings of gravel. The fact is that the London Clay, which lies below, passes up into the Bagshot Sands by alternations of sand and clay. These mixed soils occur also over the area east of Epping, near Theydon Bois, by Gaynes and Ongar Parks, and elsewhere.

More definite areas of Bagshot Sand are to be found in many parts of south-eastern Essex, at Hadleigh and Rayleigh, at Langdon Hill, at Billericay, Stock, and near Ingatestone, at Kelvedon Hatch, Brentwood, Warley and Southweald, and again at Crabtree Hill, near Lambourne. Here the sands are overlain in places by pebble-gravel.

Again, small areas of Bagshot Sand are found at Highgate, Hampstead, and Harrow, where also, towards the base of the sand, pebbly layers with ironstone occur. The junction with the underlying London Clay is at these localities also marked by alternations of sand and clay, as shown in excavations on the Kidderpore estate, West Hampstead, on the higher parts of Haverstock Hill, and in foundations for the Drawing School at Harrow. The same features are present over parts of Richmond Park and Wimbledon Common, and by Thatched House Lodge on Kingston Hill; while east of Copse Hill, Wimbledon, two outliers of Bagshot Sand covered with pebbly gravel have been observed. At Hampstead the Sand is from 60 to 80 feet thick, and it has been extensively dug on the Heath, where small patches of gravel likewise occur. (See Fig. 5.)

The more extensive mass of Bagshot Beds forms an important residential district, over a large area westwards from Esher and Weybridge to Ockham Common, Woodham, Woking and Horsell, Ottershaw, Virginia Water, Englefield Green, Sunningdale, Sunninghill, Ascot, Easthampstead, Wokingham, Finchampstead, and Aldershot. There the Bagshot Beds, almost wholly sands, range to upwards of 100 feet thick. Taken as a whole the area of the Bagshot Beds forms a picturesque, heathy country, for the most part dry and sandy, and with many fir-trees; it is from 100 to over 400 feet in elevation, and eminently adapted for building-sites

Thanet Sand.

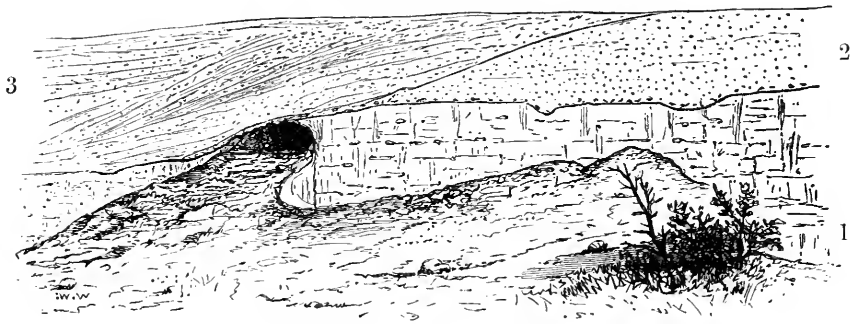
These deposits consist mainly of fine sand or loamy sand, and they border the Chalk from Leatherhead, by Epsom, Ewell, Cheam, Sutton, Carshalton and Beddington, to Croydon. Their outcrop is so narrow that it is not distinguished on the map from the Woolwich and Reading, and the Blackheath Beds. Indeed these sands exercise little influence on the land, and they do not occur to the north-west of London. From Croydon they extend by Addington, Keston and Farnborough to Orpington, Swanley and Crayford (Fig. 8); and the breadth of their exposure becomes more pronounced at Erith and Woolwich than elsewhere in the neighbourhood of London. The thickness of the Thanet Beds is from about 12 feet (at Leatherhead) to 60 feet. They furnish dry and healthy sites for houses.

Upper Greensand.

Between Guildford and Shalford, along the foot of the North Downs, and thence extending north of Shere and Gomshall to the foot of Box Hill, near Dorking, there is a narrow belt of sloping ground formed of greenish sand and calcareous sandstone. These strata, known as the Upper Greensand, are from 25 to 60 feet

thick, and usually form a dry and sheltered tract of ground. Further on, to the north of Reigate, at Gatton and Merstham, they occupy a somewhat broader belt, and are better adapted for sites of houses. See (Fig. 9.) In this region the stone-beds have since early times been quarried for building-stone and hearth-stone. Eastward the strata again form a narrow belt that extends by Titsey and Chevening to Otford, but disappears at Kemsing.

FIG. 8. *Chalk-pit west of Crayford Brickyard.* (W. Whitaker.) *



1. Chalk. 2. Thanet Sand 15 ft. 3. Brickearth or loam 25 ft.

On the northern side of the London Basin, the Upper Greensand appears below the Chalk escarpment, north of Wendover and Prince's Risborough. It comprises green sand, marl and calcareous stone (malmstone), altogether about 25 feet thick.

LOWER GREENSAND.

Far more important as a residential area, is that occupied by the Lower Greensand of Surrey and Kent—a tract separated from the Upper Greensand on the north by a narrow vale of Gault clay. The Lower Greensand consists in its upper part of loose sands, the purer varieties of which have been used for glass-making; and these sands, white, brown or green, are occasionally cemented into blocks of hard rock, as at Ightham. This division, known as the *Folkestone Beds*, is from 100 to over 200 feet thick. Lower down in the series, but occupying a small area, are beds of clayey sand and clay, which outcrop to the south of Reigate, and extend eastwards through Nutfield and Bletchingley to Tandridge. Layers of fuller's earth are worked in these beds at Nutfield. They are known as the *Sandgate Beds*, and are sometimes about 50 feet thick. Below are thick beds of calcareous sandstone, occasional limestone, and sands, with ironstone and chert. These are known

* "Geology of London," vol. i., fig. 6, p. 112.

as the *Hythe Beds*, and they form the prominent escarpment. Their thickness increases from about 90 feet at Maidstone to about 250 feet at Godalming. The base of the series comprises a band of clay and loam, known as the *Atherfield* Clay, sixty feet thick in places; this occupies but a narrow belt of country, and merges into the thick Weald Clay which lies below it. (See Fig. 9.)

In the area under consideration the Lower Greensand may be said to vary in thickness from 250 to 450 feet. It occurs below the high scarp of the North Downs, and, extends from the neighbourhood of Farnham, Hind Head, Haslemere, and Godalming, eastwards past Shalford, Albury, Shere, Gomshall, Abinger, Leith Hill, Dorking, Reigate and Redhill, and onwards to Godstone, Oxted, Limpsfield, Westerham, Sundridge, and Sevenoaks. Still further it extends by Seal and Ightham to West Malling and Maidstone. Along this course it forms a belt, of varying width, of hilly and for the most part dry and sandy country of exceedingly picturesque character, there being many heaths, commons, and plantations of firs. It is admirably adapted for healthy residences, as indeed the numerous mansions and villas make manifest. Along its southern borders it rises from about 500 to 965 feet at Leith Hill, in bold scarps which constitute the range of hills overlooking the great vale of the Weald Clay to the south. (See Figs. 1 and 9.) The higher elevations are fairly bracing.

Another tract of Lower Greensand, far north of London, extends from near Leighton Buzzard to Brickhill, Woburn Sands, Aspley Guise, and Ampthill. Although capped here and there by Boulder-clay, and containing bands of fuller's earth and clay, it is famous for its generally dry and healthy soil and salubrious air. This pleasant region, from 300 to over 500 feet in elevation, overlooks the great clay-vale which extends from Fenny Stratford in a south-westerly direction to Aylesbury.

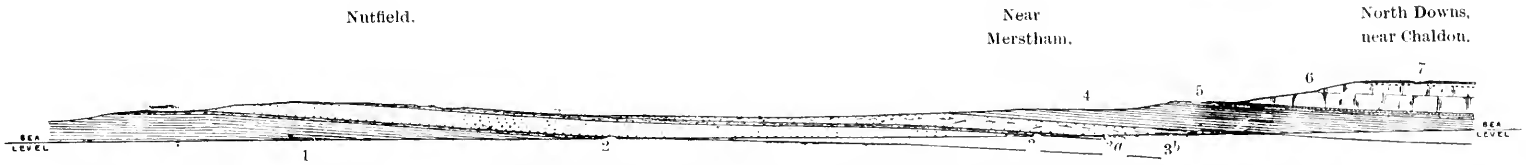
Mixed Subsoils.

Hastings Beds.

Beyond the vale of Weald Clay, before alluded to, there is a varied tract of sandy, loamy, and clayey country formed by the Hastings Beds. These comprise in downward succession the *Tunbridge Wells Sands and Sandstones* (220 to 350 feet), which include beds of clay at Grinstead and Cuckfield; the *Wadhurst Clay* (150 feet); and the *Ashdown Sand* (upwards of 400 feet) which consists of thick beds of sand and sandstone, with alternations of clay. The main divisions are separately shown on the one-inch Geological Survey Map.

Tunbridge Wells stands on this tract of Hastings Beds, which extends to the south over Ashdown Forest, to Heathfield and

FIG. 9.—*Section from the North Downs across the country east of Redhill.* (W. Topley.)



1. Weald Clay.

3b. Folkestone Beds
3a. Sandgate Beds.
3. Hythe Beds.
2. Atherfield Clay

} Lower Greensand.

7. Clay-with-flints.
6. Chalk.
5. Upper Greensand.
4. Gault.

Uckfield, and westward from East Grinstead to Three Bridges, and over Tilgate and St. Leonards Forests to Horsham and Cuckfield.

Good sites for houses occur throughout this area, the greater part of which is an elevated sandy region, for the most part dry and diversified in scenery. The more loamy tracts are not usually unfavourable by reason of any special dampness in the nature of the subsoil. The clays, though sometimes exposed on the uplands, appear mostly in valleys, and occupy sloping ground where there is good natural drainage ; and they are usually covered by a loamy soil.

Curiously enough some of the sands and sandstones belonging to the Hastings Beds are so fine in grain that in places, as Topley has remarked, " the soil holds up water almost as well as clay." Hence in examining the country " strict allowances must be made for the weather," as the percolation after heavy rain may be very slow.

In a number of places the sandstones appear at the surface as natural rocks, of which well-known examples occur near Tunbridge Wells.*

Woolwich and Reading Beds.

These comprise alternations of sands, shelly layers (mostly clayey), pebble-beds or gravel, and mottled plastic clay. The sands are often brightly coloured red and green, and there also occur buff and white sands, locally indurated in great masses like greywethers. Seams of peat and lignite are occasionally met with, but the black staining of layers is sometimes due to manganese-ore.

The subsoil is essentially a mixed one, and so irregular are the strata that actual excavation would often be needed to determine the nature of a site—whether on gravel, sand or clay. (See Figs. 7, 10, 11, 12.) The strata are from 25 to 50 feet thick, but they occupy very limited areas at the surface in the vicinity of London.

Fig. 10.—*Section across the outcrop of the London Tertiary Strata.*

1. Chalk. 2. Thanet Beds. 3. Woolwich and Reading Beds. 4. Blackheath Beds. 5. London Clay.

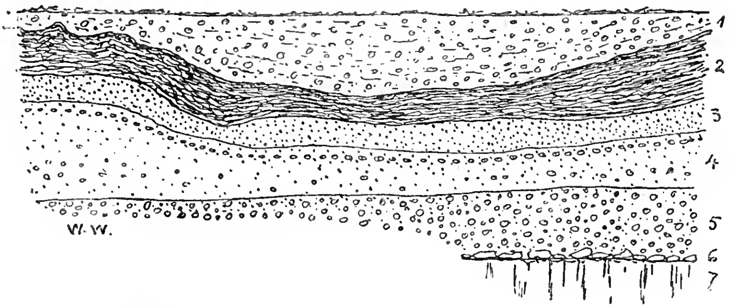
They appear from beneath the London Clay along the borders of the Chalk in a belt extending from Hoddesdon, near Ware, through Hatfield Park to North and South Mimms, Shenley, Radlett, Letchmoreheath, and Bushey near Watford, to Northwood and Harefield. Straggling inlying masses appear at Pinner, Eastcote, Ruislip, and Ickenham. At Radlett the pebble-bed is locally

* See W. Topley, " Geology of the Weald," *Geol. Survey*, 1875, pp. 245-249.

cemented into conglomerate, known as the Hertfordshire pudding-stone. Westwards the strata occur below gravel at Gerrard's Cross and Beaconsfield; they appear at Wargrave and Reading, and in the picturesque outliers of Lane End, W. of High Wycombe, and Nettlebed, N.W. of Henley-on-Thames.

South of London the Woolwich and Reading Beds outcrop between the London Clay and Chalk in a narrow belt from Merrow and the Clandons, N.E. of Guildford, to Effingham and Leatherhead. From Leatherhead onwards by Ashtead, Epsom, Ewell, and Sutton to Croydon the strata rest on the Thanet Sand, but they are concealed by gravel, between Carshalton and Croydon. In this region they practically separate the London Clay area on the north from that of the Chalk on the south.

FIG. 11.—*Section south of Bushey Station, near Watford.* (W. Whitaker.) *



1. Gravel
2. Mottled Clay
3. Sand
4. Sand with layers of flint-pebbles } Reading Beds.
5. Pebble-gravel
6. Layer of flint
7. Chalk.

East of Croydon, where the Woolwich and Reading Beds appear from beneath the Blackheath Beds, the outcrop from Addington to Farnborough is too small to exercise much influence on the ground. (See Fig. 7.) More marked, however, are their features along the borders of the Thames valley from Erith to Woolwich and Greenwich. They occur also over small areas at Lewisham, Peckham and Dulwich.

From the limited outcrop, and from the occurrence of much sand and gravel in this group of strata, it cannot be considered as furnishing sites liable to be injurious by reason of dampness unless in low lying situations. A particular house may happen to be placed on clay, but even on that account if it be well constructed no serious objection could be taken to the site.

* "Geology of London," vol. i., fig. 32, p. 199.

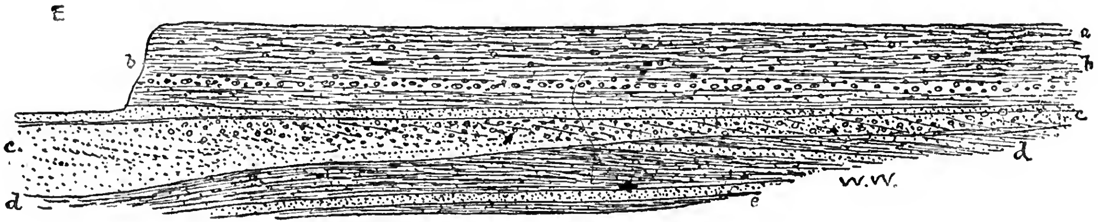
FIG. 12.—*Cutting on the South-Eastern Railway north of Mottingham.* (W. Whitaker.)*

			Feet.
1.	Sand with layers of clay	about	15
1′.	Clay with layers of sand		
2.	Shelly clays with hard shell-rock		11

		Feet.	
3.	Mottled plastic clay - -	7 or 8	Woolwich and Reading Beds.
4.	Dark sandy clay - - - -	½	
5.	Sand with layers of pebbles - -	15	

6. Thanet Sand.

FIG. 13.—*Section in Brickyard at Stoke Newington.* (W. Whitaker.)†



		Feet.
a.	Soil - - -	about 1
b.	Loam - - - -	7
c.	Sand and Gravel -	1 to 7

		Feet.	
d.	Loam - -	about 2 to 4	Valley Drift.
e.	Sand and Loam.		

* "Geology of London," vol. i., fig, 27, p, 166.

† *Ibid.*, vol. i., fig, 73, p. 403.

BRACKLESHAM BEDS.

This group comprises clays, loams, and greenish sands, that attain a thickness of 20 to 40 feet. The more clayey portion, usually at the base, holds up water, gives rise to tracts of damp peaty ground, where the overlying sand may be waterlogged, and supports an occasional sheet of water like that of the Fleet Pond west of Farnborough. The nature of this clayey ground is, however, somewhat modified by the downwash of sand and gravel from the more elevated tracts, such as the Chobham Ridges; and much of it is under cultivation.

The lands south of Sunningdale Station, over part of Bagshot Heath and the village of Bagshot, also Windlesham, Bisley, Pirbright, and Worplesdon, Ottershaw Park, and Brox are included in this mixed area. St. George's Hill, near Weybridge, is an outlying tract of Bracklesham Beds capped by gravel.

VALLEY BRICKEARTH OR LOAM.

The Brickearth associated with the valley-gravel is a brown loam, or variable sandy clay, which has been extensively used in the manufacture of bricks. The stiffer portions are practically impervious, and hold up water on level tracts of ground; but the lighter varieties are more absorbent, and allow the surface-water to pass slowly downwards.

The loam occurs irregularly, with gravel occasionally above it, and usually with gravel beneath it. (See Figs. 12, 15.) Its actual boundaries at the surface are somewhat vague. The soil above both gravel and loam, as before mentioned, is well adapted for nursery-grounds and market-gardens: while in general the areas occupied by the loam are suitable for residential sites.

There are tracts of this brickearth at Enfield, Edmonton, and Tottenham, on the western border of the Lea valley, and further east at Ilford, Upminster, and South Ockendon. Again, at Highbury New Park and Stoke Newington, there was an extensive tract of brickearth, but over large portions of the area the good earth has been removed for brick-making, while the pits have been filled with rubbish. Shepherd's Bush, West Kensington, Ravenscourt Park, Acton, Turnham Green, Chiswick, Gunnersbury, and Brentford are to a large extent situated on brickearth; it is worked for brick-making between Uxbridge Road and St. Quintin's Park, and was formerly dug on Campden Hill, to the north-east of the Kensington Waterworks Reservoir, where the brickearth rested on from 12 to 18 feet of sand. It occurs also over considerable areas at Southall, Hayes, Heston, Harlington, Harmondsworth, West Drayton (east of the railway-station), Langley and Slough.

Parts of Isleworth, Twickenham, Feltham and Laleham, Kingston-on-Thames and Barnes are situated on the brickearth. There are also surface-layers of loam at Datchet, at Parson's Green, Bloomsbury, Old Ford, Bethnal Green, and Shoreditch.

The following sections show some of the local variations in the strata :*—

Brentford. (W. Gravatt.)

	Feet.
Loam	9
Gravel	7
Loam (1 to 9 feet)	5
Sand and gravel (2 to 8 feet)	4
	25

Kensington. (W. Whitaker.)

	Feet.
Clayey brickearth	12
Coarse gravel over finer sandy gravel	23
	35

Endsleigh Street, Euston Square. (Dr. H. Hicks.)

	Feet.
Made ground	8
Clay	7
Sand	2
Gravel	5
	22

Highbury New Park. (H. B. W.)

	Feet.
Made ground	2
Loam	18
Sand	9
Peat	4
Gravel and sand	8
	41

Clay-with-Flints and Plateau Loam.

On the higher portions of the Chiltern Hills from Henley-on-Thames and Great Marlow to Prince's Risborough, High Wycombe, Amersham, Chesham, Hampden, and Wendover, and eastwards to Bovingdon, Great Berkhampstead, Hemel Hempstead, Abbots Langley, and St. Albans, and thence northward to the neighbourhood of Harpenden, Knebworth, etc., there are accumulations of Clay-with-flints often associated with Drift gravel and loam, which serve to conceal the Chalk and to render the soil more fertile. On the Chalk of the North Downs there are likewise extensive tracts of Clay-with-flints and loam, and accumulations of rough flint-gravel. These occur east of Guildford on the Downs of Merrow

* See Whitaker, "Geology of London," vol. ii., *Geol. Survey,* 1889.

and Clandon, Netley Heath and Runmer Common, on Headley and Walton Heaths, at Banstead, Coulsdon, Chaldon, and Caterham, and eastwards from Warlingham, Farley, Downe, Knockholt and Halsted to the hills near Shoreham.

The Clay-with-flints is partly a residue from the superficial weathering of the Chalk, portions of the limestone being carried away by water holding carbonic acid, and the flints with a small amount of red earthy residue being left on the surface. Commingled with these are relics of Tertiary clays, sands, blocks of greywether-sandstone, and pebble-beds: remnants of deposits which formerly extended over a wide area of the Chalk uplands. They include tracts of loam, worked for brick-making, and these are separately coloured on the map.

These mixed subsoils occur on the plateaus, but do not themselves occupy the valleys, although a subsequent downwash of the materials may be spread over many of the slopes, and an accumulation of loose flints may occur in the bottoms of the valleys. The deposit as a whole is but partially pervious, and it may be locally useful in keeping surface-contamination from wells sunk into the Chalk.

The Chalk being liable to dissolution by carbonated water, its surface is frequently penetrated by irregular cavities known as "pipes" or "sand-galls." Noteworthy examples occur at Harefield. (See Fig. 20). The superincumbent gravel and clay-with-flints may gradually subside into these hollows, but in some instances this has not been the case, the superficial deposits remaining for a long period undisturbed, and then suddenly "caving in." Hence foundations need to be carefully tested. (See p. 42.)

The thickness of the Clay-with-flints and loam naturally varies considerably and often abruptly, according to the irregularities in the underlying Chalk. It may be from a foot to thirty feet and more.

Generally speaking, the areas occupied by these superficial accumulations may be regarded as dry and healthy. For the most part the situations are elevated and breezy, and although there are tracts of heavy clay the character of the surrounding ground would be dry.

Clay.

Boulder Clay.

At Finchley there is an elevated tract of stony and chalky clay and loam, 10 to 25 feet thick, known as the Boulder Clay. It is a tough, gritty clay with pebbles of chalk, flints, and a great variety of stones and fossils derived from different strata. Occasionally it includes huge transported masses of Chalk, Jurassic clay, etc. It is for the most part impervious, though, owing to the quantity of chalk and other stones in it, it is by no means so tenacious as the

London Clay. At the surface the chalk and other calcareous stones in the Boulder Clay may be removed by dissolution, so that the soil and immediate subsoil may be a brown stony loam or clay.

The Boulder Clay extends over Finchley from near Whetstone to the brow of Muswell Hill, and in this area it overlies gravel and sand. (Fig. 2.) Tracts of it occur at Bricket Wood, between Watford and St. Albans, and again at Primrose Green and Smallford, to the east of St. Albans. Small patches of the same subsoil occur here and there, on Enfield Chase and Cheshunt Common and between Little Berkhampstead and Hoddesdon. In Essex there are tracts of it at Epping village, Theydon Bois, Chigwell Row, and Lambourne; and larger areas to the east and north-east, where it forms excellent land for wheat and beans.

Fig. 14.—*Section near Tile Kiln Farm, Widford.*

4. Gravelly soil. 1 to 2 feet.
3. Boulder Clay 2 „ 6 „
2. Sand } 12 feet seen.
1. Gravel }

The Boulder Clay as a rule would form a good firm foundation. In many of the situations above mentioned the land is naturally drained, while in other cases and especially where an extended area is covered with Boulder Clay, as in north Essex, the ground will require artificial draining.

The area taken up for the "Garden City" at Letchworth, between Hitchin and Baldock, is mainly chalky Boulder Clay, with some gravelly patches, overlying Chalk.

The occurrence of Boulder Clay and of underlying gravels and sands is somewhat irregular. Sometimes on one side of a valley, as in that of the Roding above Abridge, there is gravel beneath the Boulder Clay, while on the opposite side the Boulder Clay may rest directly on London Clay. (See Fig. 15.) In questions of local water-supply these irregularities lead to uncertainty. In the area under consideration the Boulder Clay does not occupy very extensive tracts, and it may be regarded as affording fairly dry and breezy sites.

London Clay.

Of great importance as regards the London area is the clay to which it gives name. At the surface the formation is generally a stiff brown clay, though sometimes it may be a loam; deeper down it is a mottled bluish-brown, and bluish-grey, sometimes silty, clay; and it contains nodular masses of clayey limestone

with sparry divisions, known as "septaria," also crystals of selenite and pyrites. It underlies the valley gravels and some other deposits noted previously (pp. 11, 15, 29) over the greater part of the area in and around London. (See Figs. 1, 2, 16.) The lowermost portion of the London Clay, seen along the margin where it rests on the Woolwich and Reading Beds, as at Bushey near Watford, is sometimes of a sandy or loamy nature and contains black flint-pebbles. Elsewhere it contains slabs or concretionary masses of calcareous sandstone. In many places the soil is lightened by relics of former deposits that once extended over the area, or by downwashes from hills capped by gravel. (See p. 19.) The thickness of the London Clay is often considerable, varying from 25 to 400 feet and more; but it naturally diminishes along its margin near Dulwich and Lewisham, around Shooter's Hill, near Epsom and Ewell, at Ruislip and Bushey near Watford. (See Fig. 6.) At the Bank of England and at Charing Cross the thickness is 111 feet, at Leicester Square 148 feet, and at Meux's Brewery, Tottenham Court Road, 63 feet.

FIG. 15.—*Section across the valley south of Roxwell, near Chelmsford.* *

1. London Clay. 2. Gravel. 3. Boulder Clay.

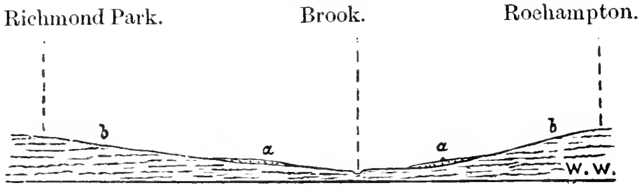
On the north-west of London this formation comes to the surface over that large tract of gently undulating meadow and pasture land which extends from the neighbourhood of Harlesden, Willesden, Cricklewood, and West Hampstead to Edgware, Mill Hill, and East Barnet, Elstree, Harrow, Sudbury, Wembley Park, Alperton, Northolt, and Ruislip. Here and there in the lower grounds there are thin gravelly accumulations. The occurrence of a gravelly bed with remains of *Hippopotamus*, beneath a downwash or land-slipped mass of London Clay, was noted near Wembley Park, in the Brent Valley; and as much as 13 feet of loam and gravel was proved at one spot at Cricklewood: this, however, is exceptional.

In the north of London, the Clay forms the surface of the ground at Kilburn, Maida Vale and Regent's Park, Haverstock Hill, Camden Town, Kentish Town, Holloway, Drayton Park, Highbury

* H.B.W. in Whitaker, "Geology of London," vol. i., fig. 49, p. 318.

Vale, Finsbury Park, Harringay Park, Hornsey, and Wood Green. On the eastern side of the Lea Valley it extends over much of Epping and Hainault Forests, as well as Chingford, Chapel End, and parts of Walthamstow.

Fig. 16.—*Section from Richmond Park to Roehampton* (W. Whitaker.) *



a. Gravel. *b*. London Clay.

South of the Thames the London Clay comes to the surface at Hither Green, south of Kidbrooke and Mottingham, over the undulating tracts of Forest Hill and Sydenham, Penge, Norwood, Anerley, Beulah Hill, West Dulwich, and Streatham. Westwards it occurs over parts of Tooting and Richmond, at Surbiton, Morden, Cottenham Park, Malden, over parts of Long Ditton, and at Chessington.

The soil which overlies the London Clay is thin, and sometimes hardly appreciable, so that the ground is damp and tenacious in wet weather, as the clay absorbs a considerable amount of moisture, while in very dry weather the ground becomes hard and great cracks and fissures appear. (See p. 42.)

On the more elevated regions, whether at Mill Hill, West Hampstead, Haverstock Hill, Crouch Hill, at Sydenham, Forest Hill, West Dulwich, or Streatham, the bulk of the water after heavy rains will rapidly disappear, although the soil in gardens may remain moist. In low grounds and hollows the rain-water will collect if no artificial system of drainage is ready to conduct it away. On such situations, especially in a rural or semi-rural district, the London Clay is to be avoided by those who should not live on a damp clayey foundation. Thus the lower grounds of Brondesbury and Harlesden, of Wealdstone and other tracts between Harrow and Edgware, and at Cottenham Park and New Malden, are not to be commended in comparison with the more elevated regions of London Clay. Maida Vale and Holloway are so built over that the drainage is practically complete, and they would suffer chiefly from their low situation in comparison with more breezy localities. Further remarks will be made in the sequel on the subject of sites on clayey areas.

* Whitaker, "Geology of London," vol. i., fig. 85, p. 426.

Gault.

This is a stiff sandy or calcareous clay, from 150 to 300 ft. in thickness, which separates the Upper and Lower Greensands. It extends in a narrow band along the foot of the North Downs from Guildford eastwards as far as the northern part of Dorking. Further east it occupies a somewhat broader belt of ground by Buckland Green, and north of Reigate, below Merstham, and onwards north of Westerham to Dunton Green. The ground is comparatively low-lying and damp; it forms a vale between the Chalk and Upper Greensand on the north and the rising tracts of Lower Greensand on the south. The area is chiefly pasture land. (See Figs. 1, 9.) To the north of the London Basin the Gault forms part of the Vale of Aylesbury.

Weald Clay.

This is for the most part a stiff clay 600 to 900 feet thick, which occupies a broad area of low-lying and gently undulating ground. The vale extends from Chiddingfold to Cranleigh, Ewhurst, Ockley, Holmwood Common, Horley, and Crowhurst to the neighbourhood of Tonbridge; and it is bounded on the north by the ranges of Lower Greensand of Leith Hill, Sevenoaks, &c. On the south rise the higher grounds of the central Wealden area, formed by the Hastings Beds. (See Figs. 1 and 9.)

Like other great clay-vales this region is to be avoided by those to whom a low-lying and generally damp subsoil is inimical. The meadows bordering the streams are apt to be flooded in seasons of heavy rain; while during a drought the ground is very much fissured.

Here and there the soil is ameliorated by coverings of loam and gravel, as near Cranleigh, along the Mole valley at Horley, and at Edenbridge; again the clay locally contains thin sandy layers and an occasional band of Sussex marble (*Paludina*-limestone); but the area in general is necessarily damp compared with the sandy uplands which border it. In hot and dry weather the district tends to be relaxing; in cold weather, where unprotected, it may be swept by chilling winds. Great part of the area is well timbered, and picturesque.

Limestone.

Chalk.

This important formation consists mainly of soft and more or less permeable white limestone, with bands of nodular flint in its upper portion; in the lower portion flints are much less common, and at the base the Chalk becomes somewhat clayey, and is known as Chalk Marl. In mass it is from 620 to over 700 feet in thickness, becoming thinner of course along its margin near the outcrop of the Upper Greensand and Gault.

In London the Chalk appears at the surface, through disturbance of the strata, in small tracts north of Lewisham, at Charlton and near Plumstead, where old chalk-pits have been converted into pleasant gardens. It comes to the surface also in an in-lying tract at Windsor, the Castle being built upon it.

Elsewhere the Chalk constitutes the broad margin of the London Basin, appearing over much of the region north-eastwards from Henley-on-Thames, Great Marlow, Maidenhead and Taplow. The joint Railway of the Great Western and Great Central traverses the Chalk tract at Loudwater, High Wycombe, and onwards to Princes Risborough. The Metropolitan Railway has opened up a large area of this country at Rickmansworth, Chesham, Amersham, Great Missenden, and Wendover; while the London and North Western Railway traverses the Chalk belt at Watford, Kings Langley, Hemel Hempstead, Berkhampstead, Tring and Dunstable. The Midland Railway crosses it at Radlett, St. Albans, Harpenden and Luton; the Great Northern at Hatfield, Hertford, Welwyn, Stevenage, Hitchin, Baldock and Royston; and the Great Eastern at Ware, Bishops Stortford and Saffron Walden.

Along the north-western margin of this area the Chalk forms the elevated range of the Chiltern Hills and their continuation in the Dunstable, Luton and Royston Downs; and there the Chalk is comparatively free from superficial coverings of gravel, loam, etc. Elsewhere, it is largely covered with patches of clay-with-flints, loam, Boulder Clay, and gravel, which occupy the plateaus, while the Chalk is exposed along the borders of the valleys. These coverings are seldom of great thickness, and they do not much interfere with the generally dry and healthy character of this great tract of country. The local water-supply requires, however, to be carefully considered, as so much of the ground is porous, and water obtained from shallow wells sunk into the Chalk in some situations is liable to contamination from cess-pits, ill-constructed sewers, grave-yards, cemeteries, &c. (See Fig. 1.)

On the southern side of the London area the Chalk is less concealed by superficial deposits. It occupies the surface in a comparatively narrow belt at Guildford, widening, however, eastwards in the Downs of Clandon, Fetcham, Mickleham, between Box Hill and Leatherhead, Epsom, and Banstead. A little further to the south and east the Chalk tracts are to some extent covered with irregular accumulations of clay-with-flints, loam, and occasional sand and gravel. (See p. 30.) A large part of the area is from 300 to upwards of 700 feet in elevation. (See Fig. 10.)

The Chalk is exposed along the Darent valley, from Shoreham by Eynsford to Dartford; in an inlier at Chislehurst; and in irregular areas at Orpington, St. Mary's Cray, Crayford, and Erith. It appears also at Greenhithe and Gravesend, and on the north side of the Thames at Purfleet and Grays in Essex.

The Chalk, with the exception of its lowermost portions is porous so that rain sinks readily into the ground ; but the formation may of course be water-logged in low-lying situations. As a rule it constitutes admirable sites for building, although its soil, unless ameliorated by coverings of loam, &c., is thin, and not very suitable for floriculture. The Chalk, however, retains a certain amount of moisture which assists in keeping fresh the herbage on the Downlands. Among trees and shrubs the beech, yew, and box flourish on the Chalk soils. With regard to buildings on Chalk tracts, care must be taken to prove the security of the foundation, for reasons elsewhere noted (pp. 31, 42).

It is only of recent years that it has been possible for the higher Chalk areas to be more generally utilized for residential purposes, owing to the provision of public water-services by water-companies. Previous to this the expense of obtaining independent supplies of water from deep wells was prohibitive ; the alternative being a scanty and precarious supply from rain-water cisterns and ponds. These higher tracts are dry and bracing.

CHAPTER III.

GENERAL REMARKS ON THE SUBSOIL WITH REFERENCE TO SITES AND FOUNDATIONS FOR HOUSES.

In considering the subsoil on which a house may be situated, it is needful to bear in mind not only the ordinary variations in character and thickness of some of the formations, but also the diminutions in thickness which occur along the margin of outcrop of the strata, and those which are due to the shape or sculpturing of the ground.

Thus Fig. 17 shows the thinning of beds of gravel and loam along their margins; while Fig. 10, p. 26, shows the thinning of strata at particular points along their outcrop where the thickness has been reduced by the wearing away of portions of each formation.

FIG. 17.—*Section of Valley gravel and Loam.*

1. London Clay. 2. Gravel. 3. Loam.

If all other circumstances are favourable it may be concluded from the remarks in the preceding chapter, that the formations best adapted for healthy residences in and near London, are the porous sands and gravels and the Chalk. Those gravels on the higher grounds, also the Bagshot and Barton Sands, the Blackheath Beds, and Thanet Beds, together with the Chalk, are generally to be preferred to the Valley Gravels, which usually lie on lower ground in positions more sheltered and relaxing and more liable to contain ground-water.

The Hastings Beds, the Woolwich and Reading Beds, and the Bracklesham Beds, from their mixed character; the Boulder Clay, the Clay-with-flints and Loam, and the Valley Loam or Brickearth, from their partially retentive nature, belong to a group second in order of merit.

CLAY AND GRAVEL SUBSOILS.

The London Clay, which has naturally a moist and heavy nature should in certain areas be avoided by those who may suffer from the effects of damp. The least desirable sites are those situated in the midst of a large region of bare clay, as in the low-lying and undulating tracts between Uxbridge, Willesden and Edgware; and again between Leatherhead, Kingston, New Malden, and Morden. The same remarks apply to the broad area of Weald Clay south of Leith Hill and Reigate.

In these rural and semi-rural areas there are large tracts of land, where in wet weather the clayey soil retains its surface moisture until it is removed by evaporation or absorbed by vegetation; and the atmosphere in consequence becomes much damper than that over tracts of gravel, sand, and Chalk, and much damper than that in the clay areas now built over. In hot dry weather the clay-ground is parched and generally much fissured.

The disadvantages of living on clay are lessened by elevation, where there is good natural drainage. They are diminished also in certain areas south of the Thames between Richmond and Croydon, where the clay-tract is much broken up by coverings of gravel.

Artificial changes indeed have exercised so much influence over the more populous parts of the London area that the naturally wet and heavy soil of the London Clay has been obscured by transported soil and gravel, as well as by ordinary made-soil and pavements. The extensive areas that are roofed and paved and the ready means of drainage, have tended to make London much drier than it used to be. Hence elevation and situation have there come to be of more importance than the original soil or subsoil.

In considering the respective merits of clay and gravel, it must be remembered that while clay and loam absorb much moisture, gravel and sand hold water, and that in a bed of gravel resting on clay, the amount so held may be large. Where the foundations of a house have been carried down to the clay, the excavation forms a sort of tank into which water may, and often does, accumulate from the surrounding gravel or sand. It has thus been found, in a number of cases, that the basements of houses built on these porous deposits are damper than those constructed on clay, if the basement-floors and foundation-walls are not rendered impervious, or if the subterranean flow of water is not otherwise checked by means of artificial drainage around the house, and this latter precaution is rarely possible in London.

Clay, after absorbing a certain amount of water at the surface, throws off the bulk of the rainfall, and it is only in the absence of natural or artificial drainage that the water accumulates. It is, therefore, better to reside on a bare clay-foundation in a district where the slopes provide a system of drainage, than on a flat or low-lying area where thin gravel rests on clay, and water can accumulate in the subsoil.

Mr. G. J. Symons has remarked that "a house on a clay soil is not necessarily more unhealthy than one on gravel,"* and my own observations quite accord with this view, so long as the site is not in a great clay-vale. Clay, moreover, serves to keep impurities from water-bearing strata beneath it; a fact of importance in rural districts.

* *Trans. Sanit. Inst.*, vol. i., 1880, p. 186, see also "The Soil in relation to Health," by H. A. Miers and R. Crosskey, 1893.

Contamination of Subsoils.

One drawback to a residence on a porous stratum underlain by clay is the liability to contamination of this porous layer. So many villages are placed, originally for the sake of water-supply, on outlying tracts of gravel and sand, or along the outcrop of sands and limestones, that the subsoil has become greatly polluted from cess-pits, sewage, grave-yards, and other sources. In cities, again, leakage from brick-drains or imperfectly cemented pipes tends to render porous soils and subsoils very unwholesome. Even leakage from gas-mains is a source of poison to the air, and although Dr. Poore remarks: "It is conceivable that the impregnation of the soil by coal-gas may have helped to stop the growth of noxious microbes which make the soil their habitat,"* yet coal-gas will destroy useful as well as deleterious microbes.

Water is usually present in the porous strata, and when the level of this subsoil-water rises, impure air is expelled into basements of houses if they are not properly cemented. Houses built on rubbish may suffer in the same way from the uprising of polluted air. In the Lea valley outbreaks of diphtheria, and in some places diarrhœa, have been attributed to these causes, but, as Dr. H. F. Parsons informs me, they are probably predisposing rather than exciting causes. Hence it is that gravel and sand may require as solid a foundation of asphalt or other well-cemented covering over the basement-floors as any habitation on clay, so as to prevent foul air as well as moisture rising from the subsoil. Concrete, being pervious to air, should not be used without a covering of Portland cement or asphalt.†

Temporary fluctuations of the ground-water have been known to produce typhoid fever, when heavy rainfall has followed a period of drought, over an area where the porous subsoil was contaminated. The investigations of Sir George Buchanan have shown that the permanent decrease of water in the soil and subsoil by improved drainage is most beneficial, and it has lowered the consumption death-rate.‡ Dampness of soil, especially in exposed

* "London (Ancient and Modern) from the Sanitary and Medical point of View," 1889, p. 35.

† See K. D. Young, *Trans. Sanit. Inst.*, vol. xv., 1895, pp. 40–42; B. Latham, *Ibid.*, vol. viii., 1887, p. 174; and Dr. C. R. C. Tichborne, *Ibid.*, vol. x., 1890, p. 283.

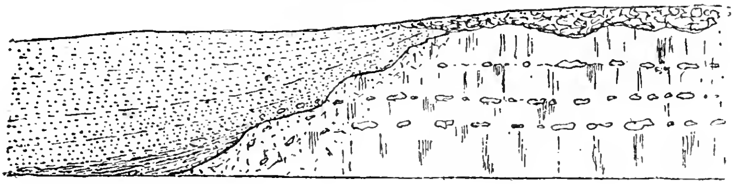
‡ Report of Medical Officer of the Privy Council for 1867, 1868. See also Whitaker, *Geol. Mag.*, vol. vi., 1869, p. 499; Topley, Address to Section III. *Trans. Sanit. Inst.*, vol. xi., 1890, p. 215; W. H. Corfield, "Health," 1880, p. 301; B. Latham, "The Relation of Ground Water to Disease," *Quart, Journ. Metereol. Soc.*, xvii., 1891, p. 1; W. R. Maguire, *Trans. Sanit. Inst.* xiii. 1892, p. 171; Dr. S. M. Copeman, "The Influence of Subsoil-water on Health," *Ibid.*, xvii., 1897, p. 23; Dr. C. Childs. *Trans. Epidem. Soc., Lond.*, 1897-8, p. 41; and E. D. Welbourn, "The part played by the Subsoil or Ground Waters in the causation of Typhoid Fever," *Public Health*, Aug. 1902.

and bleak situations, is unfavourable not only for consumptive patients, but for those suffering from lung and kidney diseases, neuralgia and rheumatism.

The most desirable subsoil is one that is dry and clean, without any accumulation of water near the surface, and where the fluctuations of the ground-water are inconsiderable.

In rural districts the level at which water stands in wells, and the level of the outlet of springs along hill-slopes, will afford an indication of the dryness or possible dampness of particular sites.

FIG. 18.—*Section at Chalk-pit between Grays and West Thurrock.* (W. Whitaker.) *



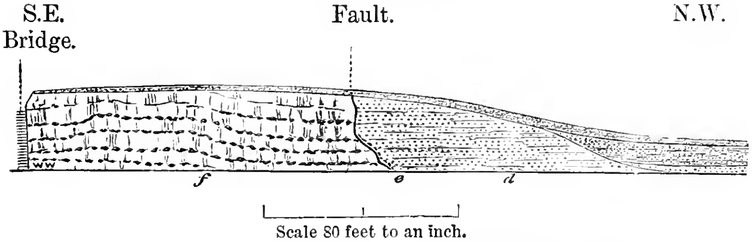
1. Chalk with flints. 2. Loam, 15 feet. 3. Soil and gravel.

FOUNDATIONS AND BUILDINGS.

For a building-site uniformity in the general character of the subsoil is desirable. To be partly on gravel and partly on brick-earth or clay, or to be on the margin of an old excavation since filled with rubbish, may lead to trouble on account of the different resistance to pressure made by the varying sub-strata. (See Fig. 18.) Such considerations apply more particularly to detached or semi-detached houses, for it is usually reckoned that in a row or terrace of houses one helps to support another.

On the margin of two formations, where sand or gravel rests on clay, springs may be expected; and when a house is constructed

FIG. 19.—*Cutting by St. John's Railway-station, near Lewisham.* (W. Whitaker.) †



Valley Drift. { *a* Soil. *b* Loam. *c* Sand. }
d Thanet Sand.
e Fault.
f Chalk.

* "Geology of London," vol. i., fig. 83, p. 418.
† "Geology of London," vol. i., fig. 7, p. 114.

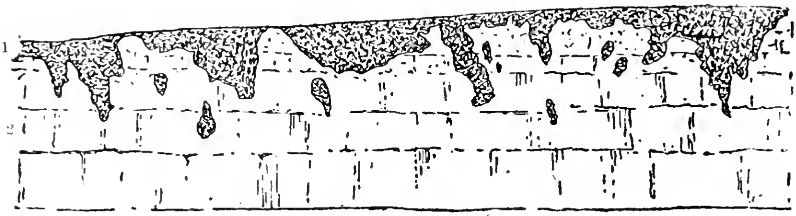
on sloping ground there should be proper provisions for drainage on the side against which the surface-water would accumulate, or from which spring-water would enter under the ground-floor. Again it is well to avoid a line of fracture where the strata are known to be displaced, as these "faults" are planes of dislocation in the earth's crust, and they are liable to be moved during earthquake disturbances.* (See Fig. 17.) Noteworthy faults are indicated on the one-inch Geological Survey maps.

Buildings on the brows of clay-slopes may suffer after long periods of drought, as the shrunken and cracked clay, when soaked with rain, swells and softens; and this change of condition tends to weaken foundations. In this way garden-walls and pavements suffer, and serious cracks may affect houses.

To build one's house on sand may be good, for if the sand be deep and occupy a considerable area, it furnishes an excellent foundation, yielding uniformly to pressure. On the other hand, a hollow in clay occupied by sand or gravel, as No. 1 in Fig. 11, would probably be charged with a good deal of water.

To build on rock, such as Chalk, may in places be bad, for this formation is liable to undergo dissolution, and great cavities or "pipes" may be formed in it, partially, but not wholly, filled with gravel and sand. (See Fig. 20.) Quite suddenly sinkings of the surface have taken place in such circumstances. Hence a Chalk foundation needs to be well tested. Good examples of these "pipes" in the Chalk may be seen in the railway-cuttings, on the London and Brighton Railway at Purley Junction, on the Great Western Railway between Reading and Pangbourne, on the Metropolitan Railway between Rickmansworth and Great Missenden, and on the Midland Railway near St. Albans.

FIG. 20.—*Chalk-pit, near Harefield.* (W. Whitaker.) †



1. Chalk. 2. Gravel, with loam, sand, etc.

Referring to buildings on the alluvial grounds of Hackney Wick, where Made Ground, peat, and clay, together 12 to 14 feet thick, overlie gravel with tidal water, Mr. F. Meeson informs me that for a light building he regards the clay as a sufficient foundation, but

* See also Prof. J. Milne in W. K. Burton's "Water Supply of Towns," 1894, p. 273.

† "Geology of London," vol. i., fig. 47, p. 307.

for heavy buildings the foundations require to be carried down to the gravel. The action of the running water in the gravel would be to carry away the clay pressed down into it by the superincumbent weight, and thus cause unequal settlements.

Settlements may be induced owing to the drainage of tracts of gravel and sand by railway-cuttings or temporarily during excavations for tunnels, and they have also been produced by the bursting of pipes that convey water. Dislocation of drain-pipes may occur through ordinary settlements, irrespective of the jerry builder; it may be caused by the shrinkage of clay in dry weather.

It is, however, well to bear in mind the common-sense advice not to purchase a house about the construction of which nothing is personally known, until at least a year has elapsed after the building of it, and it has been subjected to the varying seasons of wet and drought. Only with time can the character of the structure be well established when its erection has not been watched. In many modern houses the work that is not seen has not been so carefully executed as that which is seen. It would be well, moreover, if builders made sure that an uncontaminated soil or subsoil were the basis of all their edifices.

The "stucco-period" is happily past, but if better bricks are now used for outside work, walls too often are thinner and woodwork inferior. The fixing of a damp-proof-course above the level of the ground, and below the ground floor, is essential, as some bricks are very porous. This should consist of a layer of asphalt, sheet lead, glazed stoneware, slate, or Staffordshire blue-brick, placed above the basement brickwork to prevent the uprising of moisture. Such moisture might otherwise ascend through porous bricks to a considerable height above ground, and cause much dampness to the living-rooms.* Dr. Poore remarks "that an evergreen creeper, such as ivy, does more to keep the foundations and walls of a house dry and pure than do any of the patent impermeable applications." †

Not only are bad bricks sometimes used, but worse mortar, which in the interior of buildings is injurious, and outside readily crumbles and is washed away. For outside work it is desirable that blue lias lime (or other strong lime) be used for the mortar. Good work is cheaper in the long run, when houses are not built merely for immediate sale.

Gardens.

Those who desire especially to devote attention to the cultivation of a flower-garden will unfortunately find many drawbacks in London. They must remember that the smoky atmosphere has a poisonous effect on vegetation, and hence even if the soil

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* See K. D. Young, *Trans. Sanit. Inst.*, vol. xv., 1895, pp. 40-42.

† "Essays on Rural Hygiene," 1893, p. 36.

be fertile their horticulture may be hindered or even ruined by the dust, smoke, and noxious gases of the great city. (See p. 61.) Dr. H. F. Parsons informs me that the sterility of a town-soil is largely due to the presence in it of sulphuric acid, derived from combustion of coal and washed down by rain. This may be neutralized by the addition of lime-rubbish In many parts of London the stiff brown London Clay is so near the surface that lumps of it are dug up when the soil is turned over, and this heavy clay-soil becomes caked in dry weather and is very tenacious in wet weather. Much good soil—light loam and mould—needs to be provided in such situations, and the garden requires to be well drained. Generally speaking the gravel areas are more suitable for floriculture in London itself, and still more favourable are the loams, and the mixed soils of the Woolwich and Reading Beds, or Hastings Beds, where two or three feet of good top-soil may be expected.

Reference has been made (pp. 16, 29) to the Market Gardens in the Thames Valley to the west and south of London, situated on a loamy subsoil or on a loamy soil overlying sand and gravel. Reference has also been made to the thin Chalk soils (p. 37). Porous soils as a rule are moister in hot weather than clays, and Chalk, as is well known, may contain sufficient moisture to keep a lawn verdant when the grass suffers on other subsoils. Poplars absorb much moisture from the ground.

With regard to Nursery Grounds a large area which will provide a diversity of subsoil is of course desirable, and it is needful also in selecting suitable sites both for Nursery Grounds and Orchards, to consider the aspect, and the shelter that may be afforded from northerly and easterly winds by higher grounds or belts of trees. The loamy areas in the Bracklesham Beds to the south-west of Chertsey may be mentioned as affording good soils.

It is estimated that a supply of water equal to 400 gallons per day is desirable for each acre of Nursery land. "For horticultural purposes, the best supply is that obtained direct from the clouds, and every effort should be made to collect and preserve as much rain water as possible."*

* W. Williamson, "The British Gardener," 1901, p. 55.

CHAPTER IV.

WATER-SUPPLY AND DRAINAGE

Beyond the confines of Greater London the question of water-supply is one that may have to be considered in different localities. Shallow wells, and wells of moderate depth, may yield enough water for a cottage or even a mansion, but they may not yield a sufficient quantity for a village. Shallow wells in porous strata, such as sand or gravel, or limestone, overlying clay, as in Fig. 15, must be regarded with great suspicion in a tract where there are many habitations. A deeper well carried through a bed of clay, as in Figs. 11 or 12, into underlying sand and gravel is far preferable. Here the top-soil water must be excluded by making the well water-tight down to the clay-bed, and the water must be pumped from the base of the well. In other cases when deep wells are sunk into inclined strata, and the underground water is pent up between beds of clay, the water will rise to nearly the level of saturation in the porous strata. (See Figs. 9 and 21.) Again in deep wells carried into the central portion of a "basin," like that represented in Figs. 1 and 21, the water tapped beneath a mass of clay will rise under ordinary circumstances nearly to the general level of the plane of saturation in the underlying and bordering porous stratum. This was the case under London with the Chalk, before the water-level was locally lowered by the continued abstraction of water by pumping. (See p. 49.)

In the eastern and south-eastern parts of England water can usually be obtained from wells and borings at varying depths dependent on the geological structure. In shallow wells the water-supply, dependent on the direct rainfall, is liable to greater fluctuation than the supply from deep wells where the water has travelled some distance underground. The maximum effect of a great drought may not be felt in deep wells until some months afterwards. Fig. 21 is intended to show, as at Brentwood, shallow deposits (Bagshot Beds) that would yield water liable to contamination. By boring through the London Clay and Lower London Tertiaries to the Chalk, water might be obtained which would rise in accordance with the plane of saturation in the Chalk. Wells sunk in the Chalk of Royston Downs would find water at varying depths. The "Water Table" or permanent plane of saturation, acts like an impervious layer, and forms an hydraulic gradient over which the surplus rainfall on descending moves towards outlets on the hill-sides, where it escapes in the form of permanent springs, or during excessive rainfall in temporary outlets at higher levels or "bournes." The underground

flow of the water thus varies in direction—there is the divergent flow over the Water Table; and there is the general underground flow (in the direction of the arrow, Fig. 21) consequent on the geological structure, and dependent on the outflow of springs at Grays and on the pumping of water from the Chalk between that locality and Bishop's Stortford. The springs that issue on the scarp of Royston Downs, at Bishop's Stortford, and at Grays are overflows from the Chalk which is saturated above the levels of the outlets—the water being held up in the basin by the impervious Chalk Marl. The more copious springs issue from the Totternhoe Stone, a hard bed in the lower part of the Chalk.

Where there is a great thickness of clay—say from 300 to 500 feet, as in the Vale of Aylesbury or in the Weald, it may be more advantageous to seek a supply from adjacent hills where water-bearing strata occur, and to convey the water in pipes. In some cases it may answer better to form a reservoir by damming up a portion of the valley into which permanent springs flow. Water, again, may be taken directly from the heads of streams or from rivers, but in the latter case a very careful system of filtering is necessary. Rain-water, collected from roofs, contains many impurities such as soot, matter deposited by birds, or that washed out of the atmosphere. Special arrangements are necessary when rain-water is collected and stored for drinking-purposes. Spring and deep-well water are usually regarded as the purest supplies, which may be utilised without filtration. Chemical and bacteriological analyses are in all cases desirable, and the results should be interpreted by an expert who has also some knowledge of the sources of the water.*

London Water Supply.

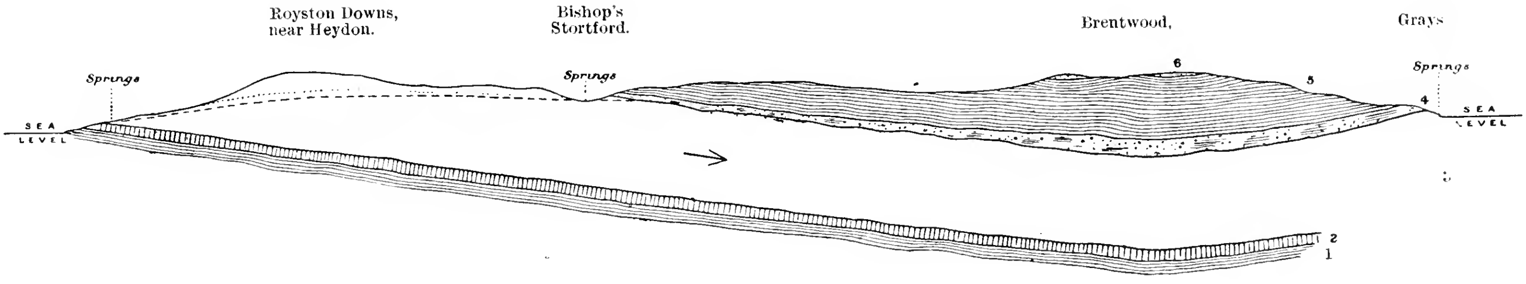
Ancient London and the many villages now engulfed in the modern city, arose on sites where a supply of drinking-water could readily be obtained from natural springs and brooks, or by means of wells. On the tracts of gravel and sand, as pointed out by Sir Joseph Prestwich, the earlier settlements were made, and the growth of London was for long regulated by the distribution of these superficial water-bearing strata.† Thus the City expanded westwards to Chelsea, Kensington and Hammersmith; southwards to Clapham and Camberwell; eastwards to Bow and Hackney, and northwards to Islington. The clay area of Camden Town, Kentish Town, Maida Vale, Kilburn, and other tracts north of King's Cross and Marylebone were not populated until a supply of drinking-water from a distance was brought in conduits.

* See "Essays on Rural Hygiene," by Dr. G. V. Poore, 1893, p. 157; "Rural Water Supply," by A. Greenwell and W. T. Curry, 1896, p. 169; "Water and Water Supplies," by Dr. J. C. Thresh, Ed. 3, 1901.

† Address to Geol. Soc., 1872, *Quart. Journ. Geol. Soc.*, vol. xxviii. p. liii.

Fig. 21.—*Section across Essex, from the Royston Downs to Grays.*

Distance about 42 miles; vertical scale exaggerated.



Drift not shown.

3. Chalk (above Totternhoe Stone).
2. Chalk Marl.
1. Gault.

6. Bagshot Sand and Pebble-beds.
5. London Clay.
4. Lower London Tertiaries (Reading and Thanet Beds.

The "Water Table" is indicated by the broken line in the Chalk under the Royston Downs—the dotted line showing the rise in plane of saturation after prolonged rainfall when springs would be given out at higher levels in the Chalk scarp.

Some of the London wells and springs in old times (1680–1810) attained fame as holy wells and spas, such as Beulah Spa, Bermondsey Spa, Holywell, Bagnigge Wells, Clerkenwell, Sadler's Wells, London Spa, Islington Spa, and St. Clement's.* Hampstead until lately utilised its chalybeate spring at Well Walk; it issues from a ferruginous sandy layer in the passage-beds between the London Clay and Bagshot Beds, and was in 1897 certified as free from contamination.

The first conduit for the supply of water to London was that of Tyburn, which was completed in 1239, when water was conveyed in leaden pipes to the City. Much water, too, was obtained in buckets from the river, and in 1582 the supply was facilitated by means of water-wheels attached to the arches of old London Bridge. Wooden conduits were then used, and a more extended system of supply to houses was introduced.

As London increased, the supplies of water obtained from the gravels became contaminated, and the water of the Thames near London Bridge was doubtless very bad. From the close of the 17th century and subsequently, companies were formed for taking water from the Thames near Charing Cross, and higher up; but since 1855, owing to the danger of tidal influence on the London drainage, no water has been drawn by any company from the Thames below Teddington Lock.

The cutting of the New River was commenced in 1608 by Sir Hugh Myddelton, and five years later the artificial channel was completed. It was not till 1619 that the New River Company was formed.† Fed by springs from the Chalk near Ware, notably by that at Chadwell, in the parish of Amwell, and receiving water also from the River Lea, the New River furnished an abundant quantity of excellent water, and has for upwards of two and a-half centuries yielded the greater part of the supply needed for the growing population of northern London. This supply has latterly been augmented by deep wells sunk into the Chalk through the London Clay, etc., at Ware, Cheshunt, Hornsey, and elsewhere.

Since the year 1790 the sinking of Artesian or "flow" wells through the impervious mass of London Clay into the Lower London Tertiaries and Chalk, has been a fruitful source of water for breweries and other large establishments.‡ The water from

* See W. Wroth, "The London Pleasure Gardens of the Eighteenth Century," 1896, pp. 3, 6.

† See J. Hopkinson, *Trans. Hertfordsh. Nat. Hist. Soc.*, vol. vi., 1891, p. 150; and vol. iii., p. lxix.

‡ The principle of Artesian wells was ascertained at a very early period in Egypt, and the construction of such wells was revived at Artois, in the department of the Pas de Calais: hence the name Artesian. They did not become general elsewhere in France, and in other parts of Europe, until the beginning of the 19th century. Prestwich, "Water-Bearing Strata of the Country around London," 1851, pp. 8, 197.

the Lower Eocene sands and pebble beds (Lower London Tertiaries) which was at first drawn upon, proved in time to be wanting both in quantity and quality, although sometimes it was not to be separated from that held in the underlying Chalk. Hence it has become necessary that borings be carried deeper and deeper into the Chalk.

The chief supply of water tapped by the deep borings under London may be said to have originated in the rainfall on the Chiltern Hills and North Downs, and to have percolated through the Chalk to the central portions of its mass. When some of the earlier deep wells had been sunk, the water rose to within 40 or 50 feet of the surface, and, in a number of instances, in the lower grounds of East Essex, the Lea Valley, and at Tooting, it actually overflowed.* In 1822 water from the Chalk rose to the level of Trinity High-water mark, *i.e.*, 12·5 feet above O.D. By the abstraction of many millions of gallons of water a day the permanent water-level under Central London is now about 100 feet below Ordnance Datum, and is still being lowered. It is needful to bore into the Chalk until some fissure is met with, whence the water can freely issue; this may be at depths varying from 10 feet to 250 or more feet in the Chalk. Thus a boring made in 1893 at Chelsea was carried through gravel, London Clay, &c., and reached Chalk at a depth of 278 feet; and the Chalk was bored to a depth of 250 feet. The water-level was 72 feet below O.D. A boring made in 1903 at Finsbury reached Chalk at a depth of 204 feet, and was carried to a further depth of 246 feet in Chalk. The water-level was 95 feet below O.D.

It has been calculated that every 1,000,000 gallons of water drawn from the Chalk carries in solution one and a quarter tons of Chalk. Thus the water pumped out tends to open the fissures, but it lowers the plane of saturation, and diminishes the dry-weather flow of streams.†

In seeking water from the Chalk a shaft, where practicable, is to be recommended, as it is not only likely to touch more fissures than a boring, but galleries or tunnels can be driven to increase the supply. In a few instances borings have been made through the Chalk without obtaining any useful supply of water.

Some of the districts to which attention has been drawn extend beyond the limits of the areas supplied by the eight London Water Companies now merged under the Metropolitan Water Board (1904); but many other parts are supplied by local companies. It is to be hoped that in time the entire country will be divided into

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* See Prestwich, "Water-Bearing Strata of the country around London," 1851, pp. 3, 45, 69.

† J. Hopkinson, *Trans. Hertfordsh. Nat. Hist. Soc.*, vol. vi., 1891, pp. 148, 149.

districts to be supplied with good drinking water. At present the inhabitants of many a small country village ill supplied with water, are not in a position to pay for the needful deep boring or reservoir. Especial attention was drawn to this subject nearly thirty years ago by the Society of Arts. A Public Congress was summoned by the Council, and the subject was very fully discussed, and reported on in 1878. A practical scheme, however, has still to be formulated and carried out.

The area supplied by the Metropolitan Water Board extends around London to Ware in Hertfordshire, to Romford in Essex, to Surdridge and Chevening in Kent, and to Esher in Surrey.* All the original Metropolitan Companies, except the Kent Company, derived great part of their supply from the Thames (at or above Hampton) and the Lea, supplemented in some cases by water obtained from wells. The Kent Company was supplied wholly by deep wells. Moreover, it was satisfactory to learn from the Report of the Royal Commission on Metropolitan Water Supply (issued in 1893) "that the water, as supplied to the consumer in London, is of a very high standard of excellence and of purity, and that it is suitable in quality for all household purposes." The eight companies in 1902 had to supply a population of more than 6,000,000 persons and to deliver a daily average of 211,500,000 gallons, of which 48,000,000 gallons were obtained from wells and springs, and the rest from the Thames and Lea.

DISTRICTS SUPPLIED BY THE METROPOLITAN WATER BOARD.

Former Metropolitan Water Companies.	*Supply.*	*Localities in the District Supplied.*
Chelsea District	River Thames at W. Molesey and Gravel Wells	Bloomsbury, Chelsea, Fulham, Marylebone, Westminster.
East London District	Lea (near Chingford), Thames at Sunbury, Gravel and Chalk Wells	Buckhurst Hill, Cheshunt, Chigwell, Chingford, Islington, Tottenham, Stepney, Stratford.
Grand Junction District	Thames near Hampton and Gravel Wells	Acton, Chiswick, Ealing, Marylebone, Paddington.
Kent District	Chalk Wells and one in Lower Greensand	Bromley, Chislehurst, Dartford, Greenwich.
Lambeth District	Thames at W. Molesey and Ditton, and Gravel Wells	Camberwell, Kingston-on-Thames, Streatham, Thames Ditton, Wimbledon.
New River District	Lea (below Hertford), Thames and Colne, Springs and Chalk Wells	Clerkenwell, Hackney, Hampstead, Islington.
Southwark and Vauxhall District	Thames at Hampton, Gravel and Chalk Wells	Barnes, Dulwich, Kew, Putney, Wandsworth.
West Middlesex District	Thames at Hampton	Hampstead, Hendon, Ealing, Hounslow, Mortlake, Richmond.

* See "London Water Supply," by Col. Sir Francis Bolton. Ed. 2, by P. A. Scratchley, 1888; "London Water Supply," by H. C. Richards and W. H. C. Payne. Ed. 2, by J. P. H. Soper, 1899; and Ann. Summary of Registrar-General for 1903, Table 18.

The Thames and its tributaries above the intakes of the Water Board contain, of course, much impurity, and in seasons of heavy rain and flood, when much foul matter is carried into the water by surface-washings, the amount of impurity is much greater than in dry weather when the river is maintained by springs. The system of filtration introduced in 1829, and since then vastly improved in various ways, especially since 1884, has, however, been very efficient in providing good water. It is now known that the slime formed on the surfaces of filter-beds contains bacilli which are the most effective agents in the bacterial purification of the water. The sand itself simply removes suspended matter, and forms a support for the active slimy layer.

It is significant that the typhoid bacillus was never found in the water supplied by the companies who drew from the Thames, though, of course, considering the immense quantity of water used and the tiny amounts that can be periodically examined, the fact must be taken *cum grano*.* Nevertheless, the character of the Thames water above Teddington has steadily improved, owing to the care taken by the Thames Conservators in keeping the main river and its tributaries as free as possible from pollution.

Although the water supplied over the London area is moderately hard, yet it is well known that many of the healthiest districts are those with hard water. Lead-poisoning may for a time be produced by soft water when conveyed in new leaden pipes. The power of dissolving lead in dangerous quantity is attributed to the peaty acids that are met with especially in moorland waters. Curiously enough, bacteria are said to increase more rapidly in water that is comparatively pure than in that containing mineral ingredients. † Nevertheless, hard and soft water appear to be equally good for drinking-purposes, when they attain a proper standard of purity. Deep well water, if allowed to stand, is said soon to become full of bacteria. If stored, such water, and also spring water, should be kept in covered reservoirs, since the access of light favours the growth in these waters of aquatic vegetation, which by its decay may taint the water. Sir E. Frankland and Dr. R. Koch adopted as a standard of bacterial purity 100 (non-pathogenic) microbes per cubic centimetre.

Chalk areas are now and again looked upon with disfavour by individuals who have a tendency to gout, because it is thought

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* E. Frankland, Discourse at Roy. Inst., *Nature*, April 30, 1896, p. 621; L. C. Parkes, *Trans. Sanit. Inst.*, vol. xv., 1895, p. 245. See also researches of Prof. H. Marshall Ward, on the Bacterial Flora of the Thames, *Proc. Roy. Soc.*, vol. lxi., 1897, p. 415.

† *Trans. Sanit. Inst.*, vol. xi, 1891, p. 234; Prof. H. Robinson *Idem.* vol. xv, 1894, p. 577; *30th Ann. Rep. Local Government Board*, 1900–01, Supplement "On Lead Poisoning and Water Supplies," by Dr. A. C. Houston.

that the chalky water would aggravate the complaint. This, however, is a fallacy, the chalky deposits in gouty persons being of a chemical nature quite different from carbonate of lime. Moreover, it is not easy in the area adjacent to London to obtain other than hard water, much of it being derived directly from wells in the Chalk. The hardness of Chalk waters is mostly of the kind known as "temporary," being due to carbonate of lime which is held in solution by carbonic acid. This it is which furs our tea-kettles and boilers, and wastes our soap.

Each degree of hardness is equal to one grain of carbonate of lime per gallon of water. The hardness may be removed by the addition of quicklime in definite quantities to the water; a process introduced by the late Dr. Thomas Clark of Aberdeen. If the initial hardness be from 15° to 20°, it can be softened to 4° or 5° by Clark's process. No potable water should contain more than 25 grains of mineral matter per gallon. A soft water has less than 6° of hardness.* Highly ferruginous water may be detrimental to health; and it has been observed that goitre is prevalent where limestone-rocks are impregnated with metallic sulphides.†

Rural Water Supply and Sanitation.

The following statistics relating to the water supply of districts outside the limits of the Metropolitan Water Board may be useful‡ :—

Urban and Rural Water Companies	*Supply.*	*Districts supplied.*
Slough	Chalk wells.	Colnbrook, Datchet, Farnham Royal, Langley, Slough, Stoke Poges.
South-west Suburban.	Chalk wells and Thames	Ascot, Egham, Feltham, Hanworth, Laleham, Southall, Staines, Stanmore, Sunningdale, Sunninghill.
Rickmansworth and Uxbridge Valley.	Chalk wells	Abbots Langley, Bovingdon, Greenford, Harefield, Harlington, Hayes, Hillingdon, Iver, King's Langley, Northolt, Perivale, Rickmansworth, Sarratt, West Drayton, Yiewsley, etc.
Colne Valley.	Chalk wells. (softened).	Bushey, Edgware, Elstree, Watford.
Herts & Essex.	Chalk wells.	Abridge, Epping, Theydon Bois, etc.
South Essex.	Chalk wells.	Barking, Brentwood, Dagenham, Grays, Havering-atte-Bower, Hornchurch, Ilford, N. and S. Ockendon, Purfleet, Rainham, Romford, Shenfield, Upminster, etc.

* For Notes on Water Softening see S. Rideal, "Water and its Purification," 1897, p. 191; also "The British Clayworker" for March, 1905, p. 390.

† Topley, *Trans. Sanit. Inst.* vol. xi., 1891, p. 224.

‡ For the above information we are indebted to "The Water Works Directory and Statistics," 1903 (Hazell, Watson & Viney). See also p 8.

Urban and Rural Water Companies	*Supply.*	*Districts supplied.*
East Surrey.	Chalk wells. (softened).	Betchworth, Caterham, Chipstead, Coulsdon, Godstone, Horley, Kenley, Lingfield, Merstham, Nutfield, Purley, Redhill, Reigate, Sanderstead, Walton, Warlingham.
Sutton District.	Chalk wells.	Banstead, Beddington, Carshalton, Cheam, Cuddington, Ewell, Morden, Sutton, Wallington, Woodmanstern.
West Surrey.	Thames.	Addlestone, Byfleet, Chertsey, Hersham, Shepperton, Oatlands, Walton-on-Thames, Weybridge.
Woking.	Chalk wells and Thames.	Bisley, E. and W. Clandon, Horsell, E. and W. Horsley, Merrow, Ockham, Pirbright, Pyrford, Ripley, Send, Wisley, Woking, Worplesdon.
Wokingham District.	Chalk well.	Wargrave, Wokingham, etc.

Other localities supplied from *Chalk wells* are Aldershot, Amersham, Aylesbury, Barnet, Beaconsfield (from Amersham), Berkhampstead, Chelmsford, Chesham, Croydon, Dunstable, Epsom, Goring, Great Marlow, Guildford, Harrow, Harpenden, Hemel Hempstead, Henley-on-Thames, Hertford, High Wycombe, Hitchin, Leigh-on-Sea, Maidenhead, Richmond, Royston, Saffron Walden, St. Albans, Stevenage, Streatley, Ware and Windsor.

Localities supplied with *soft or fairly soft water* from springs or wells in Sand and Sandstone include, from the *Hastings beds*:—Balcombe, Cuckfield and Tunbridge Wells; and from the *Lower Greensand*:—Petersfield, Godalming, Haslemere, Dorking and Sevenoaks. Reading is supplied from the river Kennet.

It should be borne in mind that the Lower Greensand and Hastings beds are variable in mineral characters, and consequently the water held by them varies locally. In parts of Kent the Lower Greensand water is hard, when derived from the sub-division known as the Hythe beds, which locally contain calcareous layers. Water from the Hastings beds sometimes contains sulphate of lime, and is sometimes alkaline from the presence of carbonate of soda.

In selecting a site outside the range of any Water Company's district, and where there is no local supply from a deep-seated or other source, the nature of the water-bearing strata must, in the first place, be carefully considered. Most villages, like those of old in the London area, have been built on porous subsoils from which the water-supply was readily obtained, and in most cases such shallow sources have become more or less contaminated. No serious outbreak of illness may hitherto have occurred, but there is always a risk of its appearance. The soakage from stables and farmyards, from cess-pits and possibly from burial-grounds, may lead to disastrous contamination in such situations, and, indeed, the attention of the Local Government Board is constantly being drawn to outbreaks of typhoid fever that arise from the

contamination of wells. That illnesses are not more frequent is due no doubt to the otherwise healthy surroundings of those who live a country life.

A bed of clay intervening between the surface-deposits and deeper-seated water-bearing strata will prevent contamination at this lower level, if the well be properly bricked and cemented to a little below the base of the porous surface-deposits. In the absence of geological conditions favourable for a supply of water by a deep well or boring, a supply must be sought from a distance. On some of the great clay-vales where local sources of water, obtained from small tracts of gravel, have been condemned, there is great difficulty as well as expense in procuring supplies.

The provision of sewers and of a piped water-service should generally go together. In the absence of a sufficient supply of water for flushing, sewers are liable to become blocked and offensive; and on the other hand, in the absence of sewers a supply of water, laid on in pipes to each house, increases the volume of waste liquid and renders its disposal more difficult; cess-pools soon fill, and unless frequently emptied they overflow and cause sewage nuisances,

The great trouble in rural districts is with the sewage. In regions where there is no main drainage and no system of water-supply, it is by no means unusual to sink "blind" or "dumb wells" into porous strata to carry off the sewage. In places where sewers are not available many difficulties would be overcome by the adoption of the pail or earth-system instead of water-closets and cess-pools. Dr. G. V. Poore has strongly advocated the plan, and experiments which he has made show that two or three feet of soil filter out bacteria, the subsoil of a greater depth being generally free from these micro-organisms. He has urged that if the solid refuse matter from houses be buried in the "living earth" (that is in the top layer of cultivated ground or natural soil), no evil should result. Putrescible matter when buried in earth undergoes decomposition without putrefaction; the danger arises from a mixture of excrement and water in sewer or cess-pool, the excrement being the ingredient against which dangerous infective properties have been proved again and again. He remarks that "The living mould is our only efficient scavenger, which thrives and grows fat upon every kind of organic refuse; our only efficient filter, a filter which swells and offers an impassable barrier to infective particles, a filter which affords a sure protection to our surface wells. When we perforate the living humus with a pipe, and take our dirty water to the subsoil, we, as it were, prick a hole in our filter, and every chemist knows what that means."* Hence, shallow wells should

* *Trans. Sanit. Inst.*, vol. xi., 1891, pp. 33, 36, 41, 47, etc.; the *Lancet*, Dec. 14, 1895, p. 1483; "Essays on Rural Hygiene," p. 192.

always be cemented some 6 or 8 feet down, and there should be no cess-pits or other subterranean receptacles for refuse in their vicinity.

Attention has been frequently directed to the evils that, sooner or later, may arise from such systems of "dead wells" and underground soakage, whether carried into the Chalk, the Thanet Sands, the Reading Beds, or the Bagshot Sands. It should be remembered that all porous strata are water-bearing, that the supply of water, especially in the case of the Chalk, may be drawn upon for drinking-purposes, and that contamination introduced into such strata may be conveyed underground to some distance from the sources of pollution. It is also well to bear in mind the important legal decision of 1885, to which Mr. Whitaker has drawn particular attention, that while every owner has the right to draw unde ground water to an unlimited extent, no owner has the right to pollute a source of water-supp'y common to his own and other wells. †

In his Address to Section III. of the Sanitary Institute (1897), Mr. Whitaker urged that where a public supply of water is obtained from porous strata, such as the Chalk, occupying large areas at the surface, then a certain tract of ground around the waterworks should be preserved from surface-contamination, whether by sewage-farm, cemetery, or other source. Shortly after those remarks were written (in the autumn of 1897) a serious outbreak of typhoid fever at Maidstone proved the great need of this precaution. On the gathering grounds of certain springs at Farleigh, utilized for the water-supply of the town, there had been not long previously an encampment of hop-pickers! The evidence showed that the epidemic was caused by the pollution of these springs.‡ Other authorities have since strongly urged that there be protective areas around all sources of water-supply, so that contamination be as far as possible prevented. §

Dr. H. F. Parsons informs me that the diseases liable to be caused by the drinking of sewage-polluted water, are those of which the infective matter is contained in the excrementitious discharges of the sick, such as typhoid fever and cholera, and in some cases diarrhœa and dysentery; also some parasitic diseases, such as intestinal worms. Scarlet fever, diphtheria, and smallpox

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* See Prestwich, Address to Geol. Soc., 1872, *Quart. Journ. Geol. Soc.*, vol. xxviii., p. lxix; Whitaker, Address to Sanitary Inst. (Section III.), *Trans. Sanit. Inst.*, vol. viii., 1887; and E. Evans, Report on Uxbridge Rural Sanitary District to the Local Government Board, 1894.

† *Trans. Sanit. Inst.*, vol. vii., 1886, p. 268.

‡ Borough of Maidstone, Report to the Local Government Board on the Epidemic of Typhoid Fever, 1897; by J. S. Davy, T. Thomson, and G. W. Willcocks, 1898.

§ J. C. Thresh, *Trans. Sanit. Inst.*, vol. xviii. 1897, p. 616; see also Report of Committee on British Forestry, 1902.

have never been traced to drinking water. Outbreaks of typhoid fever have sometimes followed the disturbance of polluted earth during the operation of laying new sewers.*

The waste-water of the house may be allowed to run away in open gutters, or be placed on different tracts of the ground every day, whereby hedgerows and shrubberies fruit and forest trees would be greatly benefited.† The dry-earth system has not been found suited for large towns; but I am informed by Mr. F. J. Bennett that it has been adopted with advantage in Brunswick, Essen, Bremen, and Zurich. In these towns peat-dust is supplied by the authorities for use in the earth-closets, and its employment has been found most succcessful on account of its deodorizing and manure-making properties.

Recent reports of medical inspectors to the Local Government Board show the need of efficient sanitary administration in many parts of the area described, even in semi-rural residential districts in the Thames Valley between Windsor and London.

One of the most deplorable practices is the way in which old quarries and pits are used as receptacles for rubbish, often of the most unpleasant nature.‡ This proceeding may have to be tolerated in out of the way places; but it is unpardonable when a picturesque common is disfigured and the air polluted by such means. When the refuse is cast into old sand, or gravel-pits, or into chalk, or other limestone-quarries, the local water-supply may be contaminated. Cliffs by the seaside or the banks of streams are not always free from these offensive and dangerous refuse-heaps, even when the locality is regarded as a health-resort! Refuse destructors should be introduced wherever possible.

Dr. Poore has written enthusiastically of "the spirited action of the city of Manchester, which has reclaimed Carrington Moss and which is reclaiming Chat Moss by fertilising the ground with the organic refuse of the city." The refuse, which includes nightsoil, road-sweepings, garbage, and cinders, is at first placed in heaps to "ripen," and is spread on the ground, when dry, and ploughed in. The ground is previously drained by a series of deep trenches.§

With regard to sewage-farms, the sites should be selected with due reference to sources of water-supply, and even to the prevalent winds. A good depth of soil is necessary, and a fairly porous

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* See also Sir R. T. Thorne, *Trans. Sanit. Inst.*, vol. xv., 1895, p. 7; and W. H. Corfield, *Ibid.*, vol. xix., 1899, p. 136.

† See Poore, "Dry Methods of Sanitation," 1894, "Essays on Rural Hygiene," 1893, p. 101, *Trans. Sanit. Inst.*, vol. xi., 1891, pp. 33, 44.

‡ See "Refuse Disposal," etc., by W. F. Goodrich, 1904.

§ "The Earth in relation to the Preservation and Destruction of contagia," 1902, pp. 116, etc.

but not fissured subsoil is desirable. The most suitable conditions would be met with in a tract of gravel and sand, if these be based on a thick clay formation having a gentle slope towards a stream-valley. Chalk and other limestone tracts are to be avoided where possible, on account of fissures, and because the strata usually are sources of water-supply.

The Chalk is sometimes protected by a downwash of rubbly and earthy chalk and marl, and if under these conditions it is fairly free from fissures, the danger of polluting the main body of water in the formation, through a sewage farm, would be remote. Lieutenant-Colonel A. M. Davies and Mr. W. C. Tyndale, in experimenting with sewage-disposal on the chalk soils of Salisbury Plain, found that sewage-bacteria penetrated nine feet of chalk after the ground had for fourteen days been deluged with sewage. They remark, however, " that when sewage is applied in an ordinary and reasonable way over the surface, no such contamination of the subsoil takes place."*

Recent researches tend to show that by means of bacterial filter-beds and other processes, sewage may be so purified that not only is all solid matter strained out or liquefied, but that the effluent water can without danger be discharged into streams and rivers. In some rare cases after land-treatment, the results have proved " so good that, apart from a knowledge of its source, the effluent might actually be regarded as a potable water of more than average purity."† Nevertheless it may rightly be urged that in no case should the effluent be discharged into a stream that is utilised as water-supply, nor into a tract with pools of stagnant water.

The sewage-works should be well above any portions of a valley liable to be submerged in times of serious floods. The irrigated fields are suitable for the growth of rye-grass, and for osier-beds.‡

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* *Trans. Sanit. Inst.*, vol. xxv., 1904, p. 649; and "Report on Sewage Disposal in the Salisbury Plain District" [War Department], 1904.

† Interim Report, Royal Commission on Sewage Disposal, 1902, p. 26; see also S. Rideal, "Water and its Purification," 1897, p. 159; W. J. Dibdin, "The Purification of Sewage and Water," 1897; Dr. S. Barwise, "The Purification of Sewage," 1904.

‡ See Prof. H. Robinson, *Trans. Sanit. Inst.*, vol. xv., 1895, p. 577.

CHAPTER V.

GENERAL SANITARY CONSIDERATIONS IN REGARD TO SITUATION AND SURROUNDINGS OF HOUSES.

In most cases a dry and a fairly open, sunny, and even breezy site is to be preferred to one that is much enclosed, whether by other buildings, by plantations, or through being situated in a sheltered valley. Sunshine in rooms is most desirable, and trees not only produce shade but they check evaporation from the ground and thus tend to promote dampness. In a town the value of a garden increases in proportion to the density of the population.

Dr. Louis Parkes has observed that "it is now generally conceded that back-to-back houses without thorough ventilation, and rooms facing narrow enclosed courts in which the atmosphere is always sunless and stagnant, exercise an unfavourable influence on health, and tend to produce an excessive mortality from phthisis, respiratory diseases, diarrhœa, and zymotic diseases generally."* Overcrowding of houses is regarded by Dr. Poore "as infinitely the greatest of all sanitary evils."

On the other hand flats, with good spaces between the blocks of buildings, may be healthy enough, better indeed than small houses or cottages that are crowded together. In flats the sanitary arrangements are good, the basements are well constructed, while the tenants are to a certain extent selected and under supervision. The chief drawbacks in the poorer class of flats may be from the impure air and dust that arise from the lower stories, and from the opportunities for the spread of infectious or contagious diseases in the buildings. In general the death-rate in flats in crowded areas is lower than that in ordinary dwellings and tenement houses; but in the multiple artisans' dwellings the death-rates from infectious diseases have been higher as regards infantile mortality, because there are more children, and scarlet fever, diphtheria, whooping cough and measles are more prevalent.†

While the growth of Inner London has led almost wholly to the effacement of nature within its bounds, yet considerable attention is paid to the preservation of open spaces, so essential to the health of the community. This is a subject that should be

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* *Trans. Sanit. Inst.*, vol. xii., 1892, p. 26; see also Sir D. Galton, *Ibid.*, vol. i., 1880., p. 121.

† Dr. J. F. J. Sykes, "Public Health and Housing," 1901, p. 58; L. C. Parkes & W. Rolfe, *Trans. Sanit. Inst.* vol. xxvi. 1905, p. 311.

constantly in view, especially in the quickly growing suburbs. Indeed the rapid increase in the number and size of buildings constructed for flats, renders it more than ever desirable that additional parks and open spaces be provided. In the county of London the area of open public spaces in 1902 amounted to 4,032 acres, or to about one acre to 752 persons.

The system of surface-draining is more complete in London than in most rural districts; and the fact that less of the rain-fall gets into the soil and subsoil is in itself an advantage. Only here and there in very low-lying situations near the river, in a badly drained garden, or in times of sudden and heavy rain when the gratings leading to the sewers become choked, when water-mains burst, or when a canal overflows, are there serious if temporary accumulations of water. Thus a severe thunderstorm on July 21st, 1897, caused disastrous floods in Stoke Newington, Hackney, and South Hornsey; roads and railways were temporarily converted into canals, a sewer burst, and the basements of many houses were flooded, not merely with rain-water, but with the overflow from drain-traps of the surcharged sewers. Moreover during severe winters when the water in mains and soil-pipes is frozen not only great inconvenience but some danger to health may arise.

The system of house-drainage (though by no means perfect), the clearance of dust-bins, and finally the supply of good drinking-water, all tend to make London, including much of the central portion, one of the healthiest cities in the world. There is much yet to be done in improving the method of collecting dust, especially on windy days, but if the principles of the Model Bye-laws of the Local Government Board (Series II. 1877) were attended to, there need be little complaint. With regard to pavements, asphalt is more easily cleansed, but it is slippery under wet and muddy conditions; wood pavement becomes in time very uneven, it is unwholesome in hot weather and slippery in frosty weather.*

Moreover, London is not so liable to those epidemics which arise in many country villages from the drinking of contaminated water. It has been estimated that the annual death-rate of the population of London in the latter half of the 17th century was nearly 80 per thousand, and in the 18th century about 50 per thousand.† The average mortality per thousand of its inhabitants is now under 19, while its population per acre is about 64. The average mortality in the outlying districts on the west, north, and south is 17, as compared with 22 in the central and eastern districts.‡

* See T. Blashill, "The State of London Streets," *Journ. Sanit. Inst.*, vol. xxii., 1902, p. 7: see also W. N. Blair, *Ibid.*, vol. xxi., 1900, p. 289.

† See *Nature*, Feb. 16, 1899, p: 366.

‡ See Ann. Summ. of Regist. Gen. for 1904; also Poore, "Essays on Rural Hygiene," p. 17; and "London (Ancient and Modern) from the Sanitary and Medical Point of View," 1889.

Fogs and Sunshine, Rain and Winds.

It is true that the dusty atmosphere of London is often trying and more or less injurious, especially in dry windy weather. On such occasions the emptying of dust-bins contributes not a little to the danger and discomfort. In calm weather the city is notorious during the late autumn and winter, from October to February, and especially in December, for its fogs; but it is not alone in this respect among the larger manufacturing towns which lie in river-valleys, nor is it much worse than these.

Ordinary mists indeed occur all over the British Isles, irrespective of soils and subsoils and elevation, but they are more prevalent in the clay vales. Mists are produced through the chilling of warm moist air by a cooler current; by the chilling effect of a river on warm moist air, and when cool moist air passes over warmer water. At night when the earth's surface has been cooled by radiation of its heat, mist may be produced through the chilling of warm moist air. Mr. John Aitken has shown that aqueous vapour requires free surfaces for its condensation, and that these are provided by dust, or even by very fine particles of ordinary salt derived from sea-spray; and that when air is filtered so that all floating particles of matter are removed then no cloud of condensed vapour is formed.*

"Wet fogs" as they are called, are produced when the particles of dust are comparatively few and the condensed moisture is excessive.

"Dry fogs," on the other hand, occur when the smoke and dust are very abundant, and while the vapour condenses on the grains of dust, the watery particles are darkened also by a coating of tarry matter arising from the combustion of coal. This delays evaporation. Dry fogs occur when the temperature is low and the pressure is high.

Added to the discomfort produced by fog, is the comparatively large amount of carbonic acid and sulphurous gases present in town atmospheres. Mr. Aitken has shown that the quantity of burned sulphur (derived from coal), that escapes from our chimneys, is most active as a fog producer, but, he remarks, "burnt sulphur is not an unmitigated evil. During fogs the air is still and stagnant; there is no current to clear away the foul smells and deadly germs that float in the air, and which might possibly be more deadly than they are if it were not for the powerful antiseptic properties of the sulphurous acid formed by the burning sulphur."† Although unpleasant in itself we thus may have some

* *Trans. Roy. Soc. Edin.*, vol. xxx., 1883, p. 337. See also W. J. Russell, *Nature*, Nov. 5th, 1891, p. 11; and C. T. R. Wilson, *Phil. Trans.*, vol. clxxxix. (A), p. 265.

† *Op. cit.*, p. 354. See also W. Mattieu Williams, *Trans. Middlesex Nat. Hist. Soc.* for 1887, p. 112; and Sir D. Galton, *Trans. Sanit. Inst.*, vol. iv., 1883, p. 35.

compensation for the unwholesome character of our foggy atmosphere. Moreover, those who have been accustomed to travel on the Underground Railway between Baker Street and King's Cross have questioned whether any microbes there could exist. They did indeed occur, but more particularly in the air of the railway-carriages.

Since electric traction has been introduced the presence of traces of ozone in the tunnels has been detected, and it is hoped that the air will now become aseptic instead of antiseptic.*

That in foggy weather the number of micro-organisms becomes greatly reduced, and many forms appear to be destroyed, has been ascertained;† nevertheless, the death-rate is found to increase through fogs. The returns of the Registrar-General, as pointed out by Dr. W. J. Russell, indicate that the main cause of the increase of death when fogs occur, is the sudden fall of temperature, not the fog itself. When, as occasionally happens, dense fogs arise, and the temperature is an average one, there is no increase in the death-rate.‡ On the other hand, Dr. Poore considers "that it is not merely the coldness of the fog which raises the death-rates, but rather the impurities, mechanical, chemical, and infective, which it contains." The fact is that both the cold and the impure atmosphere tell on the weakly, and the effects may not be produced immediately. Sufferers from bronchitis and other lung troubles are seriously affected by fog. §

Concerning the general discomfort of fog, there can be no difference of opinion; moreover, the loss of sunlight is injurious. Plants in London and at Kew Gardens suffer during such times, not only from the loss of light, but also from the sooty and tarry deposits which accumulate on the leaves. These deposits contain carbon, hydrocarbons, sulphuric and hydrochloric acids, ammonia, and mineral matter (chiefly silica and iron salts). ||

With regard to sunshine, records show that at the undermentioned localities the number of hours of sunshine were as follows :—

	1890.		1903.
Bunhill Row - -	1,157	- - - - - -	1,097
Greenwich - -	1,255	- - - - - -	1,445
Kew - - -	1,404	(1,763 in the year 1899)	1,436
Aspley Guise - -	1,419	Berkhampstead -	1,301
Eastbourne - -	1,723	Bognor - - :	1,822

* *The Lancet*, Oct. 28th, 1905, p. 1271.

† Dr. A. A. Kanthack, *Nature*, Dec. 31st, 1896, p. 209.

‡ *Nature*, Nov. 5, 1891, pp. 13, 14.

§ "Essays on Rural Hygiene," pp. 19, 150. See also Dr. J. B. Cohen, "The Air of Towns," *Smithsonian Miscell. Coll.*, No. 1,073, 1895, pp. 23, 29, etc.

|| Poore, *Trans. Sanit. Inst.*, vol. xiv., 1893, pp. 18, 23; see also Dr. W. Ewart, Report on the Counties of London and Middlesex, in "The Climates and Baths of Great Britain," vol. ii., 1902, p. 26.

The average sunshine for a year in the Metropolis is 1,240 hours, or 28 per cent. of the possible amount. It may be said, therefore, that in London we have about a quarter of the possible number of hours of sunshine during the year.

Fogs can nowhere be avoided in the London area, though they are less dense at Hampstead and Highgate, or at Streatham, than at King's Cross, Homerton, Whitechapel, or Rotherhithe. Somewhat dense fogs may extend as far south as Sutton and Croydon, or even as far up the river-valley as Walton-on-Thames, after an easterly wind has drifted the smoke-laden atmosphere in that direction.

Rain clears the atmosphere of the coarser dust-particles which favour the formation of fog, and in rainy seasons fogs are comparatively rare; but Mr. Aitken has shown that rain has little effect in diminishing the amount of the finer dust in the air.*

Rain also purifies the air of bacteria which are carried with dust, so that a wet season is generally a healthy one, especially during the summer. Rain in summer is found to be more impure than that in winter.

It may be of interest here to note the following observations made at the Kew Observatory, as they serve to indicate the general character of the climate, as it is affected by rain and wind :—

Years.	1894	1895	1896	1898	1899	1900
Rainfall: Total inches	28	22	20	18	20	21
Number of days on which 0·01 inch of rain or melted snow was recorded	183	142	155	139	135	162
Wind: Number of days on which it was from—						
North	42	47	68	45	39	58
North-east	52	45	40	37	34	33
East	40	42	33	35	57	24
South-east	13	19	15	17	20	12
South	37	30	38	43	46	44
South-west	99	88	80	96	76	94
West	50	59	55	57	59	63
North-west	32	35	37	35	34	37

* *Nature*, Dec. 30th, 1890, p. 185. See also W. J. Russell, *Ibid.*, Nov. 5, 1891, pp. 11–15; F. J. Brodie, *Ibid.*, March 5, 1891, p. 424. See also Reports of the Kew Observatory Committee, in *Proc. Roy. Soc.*; and R. C. Mossman, "Meteorology of London, 1713–1896," paper read before *Royal Meteorol. Soc.*, June 16 1897.

The rainfall in different districts may be thus tabulated*:—

——	Averages.		1903.	
——	1876–99 Depth.	1890–99 Depth.	Depth of Rain.	No. of rainy days.
London - -	25·16	22·78	38·10	179
Abinger - -	31·70	30·03	47·52	190
Sevenoaks -	27·49	26·23	37·00	176
Chelmsford -	22·96	21·22	33·75	175
Saffron Walden	24·80	24·27	33·43	192
Hertford - -	24·97	22·84	35·65	191
Hitchin - -	24·66	23·25	37·56	198
Slough - -	24·00	23·25	36·40	176

The influence of winds is, of course, all important. It may be observed that the prevalent south-west winds come across a large area of gravel-country before reaching western London, and the air on the clay-tracts of West Hampstead is certainly more salubrious than that on gravel-tracts to the south-east, where the air is more contaminated by London smoke. Referring to the presence of bacteria in the atmosphere, Dr. Kanthack has remarked that "there is an extraordinary difference between the air in Oxford Street and on Wandsworth Common"—to the manifest advantage of the air on Wandsworth Common. The amount of dust in the atmosphere, and in consequence the number of bacteria, diminish from the more populous regions to the suburbs, and to the country; and they practically "disappear at high levels and on the sea."†

Statistics show that the number and density of fogs in London increased for many years after 1841, but have decreased during the last twenty years. There were 86 in 1886, 26 in 1903, and 13 in 1900. The fact that they appear to be less dense may be attributable to the efforts of the Coal Smoke Abatement Society; to improvements in factories, and in household lighting and cooking. ‡

Breezy situations are naturally healthy, as compared not only with densely-populated districts in low grounds, but with pent-up

* H. R. Mill, "British Rainfall, 1903, 1904, pp. 173, 202.

† Kanthack, *Nature*, Dec. 31, 1896, p. 209; A. Macfadyen, *Ibid.*, Feb. 7, 1901, p. 359. See also B. A. Whitelegge, "Hygiene and Public Health," Ed. 2, 1893, p. 263; and W. H. Power, 10th Ann. Rep. of Medical Officers to Local Gov. Board, 1882, p. 330.

‡ F. J. Brodie, *Quart. Journ. R. Met. Soc.*, vol. xxxi, 1905, p. 15.; H. E. Armstrong, *Trans. Sanit. Inst.* vol. xxvi., 1905, 196; Parkes, *Ibid.*, p. 315; see also *Nature*, Jan. 12th, 1905, p. 259.

and wooded valleys. Dr. A. Haviland has pointed out that certain river-valleys exercise an important and beneficial influence on health. In those valleys which lie in the direction of the prevalent winds the air is more completely and frequently changed than in valleys which lie north and south. Where the air is constantly changed and freshened, whether inland or on the seabord, there is a low mortality from heart-disease. In pent-up valleys and in unventilated streets there is a high mortality.

The open-air treatment for consumptive patients is now generally advocated, but Dr. Haviland considered that shelter against strong winds is necessary, and that the patients would derive benefit from a residence in a warm and fertile sandstone-vale, or on sheltered and dry uplands. His observations and statistics tend to show that the highest mortality among women from malignant disease (registered under the name of cancer), occurs in valleys where the rivers periodically flood the adjacent low grounds. The lowest mortality from the same disease is found in high and dry regions, or in steep valleys where the rivers are rapid and torrential, and only temporarily flood the bordering land.*

Residential districts which, like Chelsea, Putney, and Fulham, are situated on gravel near the Thames, and are comparatively low-lying, are freshened to some extent by the currents of air that follow the course of the river.

Flowing water, so long as it does not actually contribute towards the dampness of the subsoil, is not in itself unhealthy. Where land is periodically flooded, whether by overflow of rivers or by tidal action in estuaries, the sodden ground on drying is liable to send off noxious exhalations. Subsoil drainage and cultivation have tended largely to decrease the number of cases of ague in the marshlands of Essex, Lincolnshire, and elsewhere. Salt-marshes, however, are not regarded as injurious to the same extent as the river-flats.

Malaria (intermittent fever) which was attributed to the miasmatic emanations from tainted soils, marshes, and stagnant pools of fresh water, is now known, through the researches of Major Ronald Ross and others, to be due to parasites which inhabit the blood of the sufferers, and are conveyed from person to person by the bites of mosquitoes of the genus *Anopheles*, in the salivary glands of which the parasites undergo one stage of their life-history. The larvæ of this mosquito are developed in stagnant

*"Geographical Distribution of Disease in Great Britain," Ed. 2, 1892, pp. 28. 29, 33, 234; see also remarks on Disease Maps, in "The Soil in relation to Health," by H. A. Miers and R. Crosskey, 1893, p. 123.

pools. Kerosene oil appears to kill them, but the chief remedy is in proper systems of drainage.*

For those suffering from rheumatism, throat or lung diseases, and for delicate constitutions generally, proximity to rivers or marshes is objectionable, and a higher situation with less tendency to mist should be sought.†

Breezy situations may be found, as at Wimbledon, Harrow, Hampstead, or Mill Hill, or in the higher sandy regions of Bagshot Heath; the more sheltered places must be looked for in the picturesque regions of Surrey and Kent, on the southern side of the North Downs, or in the country west of Uxbridge,

Conclusions.

The conclusions to which the foregoing remarks lead, may not be deemed very definite as regards the influence of soils and subsoils on sites for houses, or the relative importance of gravel, sand, clay, or chalk. So much, indeed, depends on the combination of all the various conditions that affect the salubrity of a district or site. One would, in fact, be disposed to conclude that it is well-nigh impossible anywhere to find all conditions in their most favourable aspect, whether in town or country, in cottage, mansion or flat. It may be desirable to avoid proximity to a stable, to a railway, and especially to a shunting-yard. Moreover, the constitutions of the several members of one family may so differ that all cannot with equal advantage reside in the same locality. Dry and bracing air may be required by some individuals; shelter from north and east winds by others. Some needful conditions with regard to situation or climate may have to be sought outside the regions described in this little work.

The area in and around London presents many kinds of subsoils, and the character of sites is modified not only in accordance with their varying nature, but also with elevation and other circumstances. London doctors appear as a rule unwilling to express views regarding the connection between subsoil and disease. Their patients come from all parts of the country and of the metropolis, and bring their complaints with them. The population, in many districts, is a very changeable one, as with the short leases of three

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* *Nature*, Aug. 3, 1899, p. 324, Oct. 5, 1899, p. 546, March 29, 1900, p. 522; and Reports on Malaria, *Royal Soc.* See also "On the Rôle of Insects, Arachnids and Myriapods, as carriers in the spread of Bacterial and Parasitic Diseases of Man and Animals. A critical and historical study," by Dr. G. H. F. Nuttall, *Johns Hopkins Hospital Reports*, vol. viii.; and Prof. Angelo Celli, *Trans. Sanit. Inst.*, vol. xxi., 1900, p. 617.

† See Hon. F. A. R. Russell, *Trans. Sanit. Inst.*, vol. iv., 1883, pp. 220–222; also "The Atmosphere in relation to Human Life and Health," *Smithsonian Misc. Coll.*, No. 1072, 1896.

years there is considerable temptation to move into a new or freshly decorated house rather than to remain and undergo the discomfort attending the presence of painters and paper-hangers. In connection with the character of the great city as a healthy place of residence, the variety of thought and scene which tend to occupy and divert the mind cannot be overlooked.

In rural districts, where every natural element should favour health, the fresh air and charms of scenery may often be the chief redeeming features. Those only can enjoy the comparative quiet, who have plenty of resources in interesting and useful occupation.

Hygienic improvements are gradually taking place, and it has been calculated that those made during the past thirty years in England and Wales have now resulted in the saving of 120,000 lives a year. Very much, however, remains to be done.*

* Those seeking further information with regard to various localities should consult the Report of a Committee of the Royal Medical and Chirurgical Society, entitled "The Climates and Baths of Great Britain," vol. i. The Climates of the South of England, and the Chief Medicinal Springs of Great Britain, 1895 [*The Climate of the South-eastern Counties, Surrey, Sussex, and Kent*, by Dr. W. Ewart, pp. 236–506] ; vol. ii. The Climates of London and of the Central and Northern portions of England, together with those of Wales and of Ireland, 1902. [*Report on the Counties of London and Middlesex*, by Dr. W. Ewart, pp. 1–80.]

CHAPTER VI.

Cemeteries.

The selection of sites suitable for cemeteries is a task requiring the most careful consideration. It is very desirable that burial-grounds be situated as far as possible from densely populated regions, and be placed in positions where the population is not likely to increase to any great extent for a long time. It is necessary that the subsoil be of such a character as to cause no pollution of the air, and that there be no pollution of underground or other sources of water-supply.

So long as earth-burial continues to be the chief system adopted in this country, the subject must constantly engage the serious attention of local authorities. It may be true, as Dr. Poore maintains, that "Rational earth-burial has never been shown to be productive of any evil;" but rational interment has not always been practised. It is admitted that a rapid decay after burial is desirable, and this can only be brought about by the use of perishable coffins and by interment in porous earth. This earth should have a depth of not less than ten feet, and graves should not be more than eight feet deep—preferably less, or from 5 to 8 feet, when (according to the "rational" system) only one body is buried in the same grave; while the level of the subsoil water should always be at least two feet below the bottom of the deepest grave.* In large cemeteries a greater depth of porous strata is desirable, as graves have sometimes been made to a depth of 20 or 25 feet. To secure the necessary conditions attention must be paid to the physical features and geological structure of the district.

An isolated tract of elevated ground, where sands and sandy loams, or sandy and loamy gravel, of considerable thickness, rest on clay also of considerable thickness, offers the most desirable site. Probably a sandy and calcareous loam is the best material for a graveyard, for a slight amount of moisture in the earth is helpful to the process of decay, though it must not be excessive. That interment should preferably be at no great depth is owing to the fact that the micro-organisms which produce decomposition are most active near the surface.†

* See Memorandum on the Sanitary Requirements of Cemeteries, Local Government Board, 1893; C. H. Cooper, *Trans. Sanit. Inst.*, vol. xv., 1895, p. 567; Rev. F. Lawrence, *Ibid.*, vol. vii., 1886, p. 283; Poore, "Essays on Rural Hygiene," pp. 38, 285; "Sanitary Condition of Cemeteries and Burial Grounds," Report by Dr. G. W. F. Young, London County Council, 1899.

† See "The Chemical and Bacteriological Examination of Soil, with especial reference to the Soil of Graveyards," by J. B. Young, *Trans. Roy. Soc.. Edin.*, vol. xxxvii, 1895, p. 759.

Stiff clay, like the London clay, is in most respects bad, as dissolution is checked, and may be retarded for many years. In wet weather open graves are apt to contain much water at the time of burial, and the re-opening of them may be attended with the risk of noxious gases. Moreover, in periods of drought, cracks may appear to a depth of 7 or 8 feet or more in clayey ground, and unpleasant and injurious emanations may arise from these fissures. Such results cannot take place in sands and sandy or loamy gravels, nor in very sandy loams, which are in themselves regarded as good deodorizers.* Coarse gravel comparatively free from any matrix is bad, and so also is broken rock, or any very loose and open material. Chalk, though considered excellent as a medium for ready dissolution, is to be condemned on account of its general utility as an underground reservoir for water-supply.

In porous soils the effluent water that escapes from hill-sides into brooks may be a source of danger if due attention be not paid to the matter. It need hardly be urged that no fresh sites for cemeteries should be selected within the county of London. It would be well if all those still used in thickly populated districts were closed, and especially those in the London Clay, the fissured surfaces of which in dry weather may lead to pollution of the air.

There are places in the Thames valley both above and below London, and at a distance from the metropolis, where valley gravel and loam rest on the London Clay, and where appropriate sites for cemeteries may be found.

Sites may also be obtained in the areas occupied by the Bagshot Sand in Essex, and especially where the loamy passage-beds into the London Clay are well developed. In this respect *geologically* the upper part of Highgate Cemetery was suitable ground *before the district was densely populated*, and the same geological conditions occur at Harrow Churchyard.

Nowadays the cemetery at Brookwood near Woking may be regarded as one of the best examples, at a sufficient distance from London, and one which fulfils as nearly as can be the requisite sanitary conditions. Those at Finchley, in the chalky clay overlying sand and gravel, are good sites geologically, and they occupy breezy situations. It is true that they are placed in a district where the population is rapidly increasing, but at present to the south of the Marylebone Cemetery there is a large area of sparsely populated ground, for the most part meadow-land. Other cemeteries on the Woolwich and Reading Beds, and Blackheath Beds, occupy suitable ground, so far as the soil is concerned. If additional burying-grounds be required they should be formed at a

* See Cooper, *op. cit.*, and Sir D. Galton, *Trans. Sanit. Inst.*, vol. vii. 886, p. 285.

further distance from the Metropolis, where the geological conditions and physical features are suitable, and where railway communication could replace transit by road.

It may, however, be mentioned that the City of London, and various parochial authorities are taking steps to provide and maintain crematoria in connection with various parish cemeteries; and it need hardly be stated that the general adoption of cremation would be a great advantage from a sanitary point of view. Moreover, there would then be no occasion to close any cemeteries as long as they possessed the requisite space for monumental purposes.

The sites of various cemeteries in and around London may be noted as follows:—

VALLEY GRAVEL:—Barnes, Brompton (*West London*), Croydon, Ealing, Fulham (*Hammersmith*), Hanwell (*Kensington* and *St. George's, Hanover Square*), Leytonstone (*St. Patrick's*), Manor Park and Woodgrange, Ilford (*City of London*), Mile End Old Town (*City of London and Tower Hamlets*), Mortlake, Plaistow (*East London*), Putney (old), Streatham, Tooting Churchyard, Wandsworth, and West Ham.

VALLEY GRAVEL and SAND, and LONDON CLAY:—Abney Park, Stoke Newington; Earlsfield (*Wandsworth*), Hither-green (*Lee*), New Southgate (*Great Northern*), Tooting (*Lambeth*).

BARTON SAND and BRACKLESHAM BEDS:—Brookwood, near Woking (*London Necropolis*).

BAGSHOT SAND (PASSAGE BEDS) and LONDON CLAY:—Highgate, Harrow.

BOULDER CLAY and GRAVEL:—Finchley (*Islington, St. Pancras,* and *Marylebone*).

THANET, WOOLWICH, and BLACKHEATH BEDS:—Plum stead, Woolwich.

WOOLWICH BEDS and LONDON CLAY:—Charlton, Brockwell and Ladywell (*Deptford, Lewisham*).

LONDON CLAY:—Camberwell, Chingford, East Dulwich (*Camberwell*), Elmer's End, Beckenham; Golder's Hill, Hendon; Greenwich, Hampstead, Kensal Green, Kingston Vale (*Putney*), Morden (*Battersea*), Norwood (*South Metropolitan*), Nunhead, Shooter's Hill (*Greenwich*), Willesden, and Wimbledon.

INDEX MAP

OF THE

SIX-INCH SHEETS

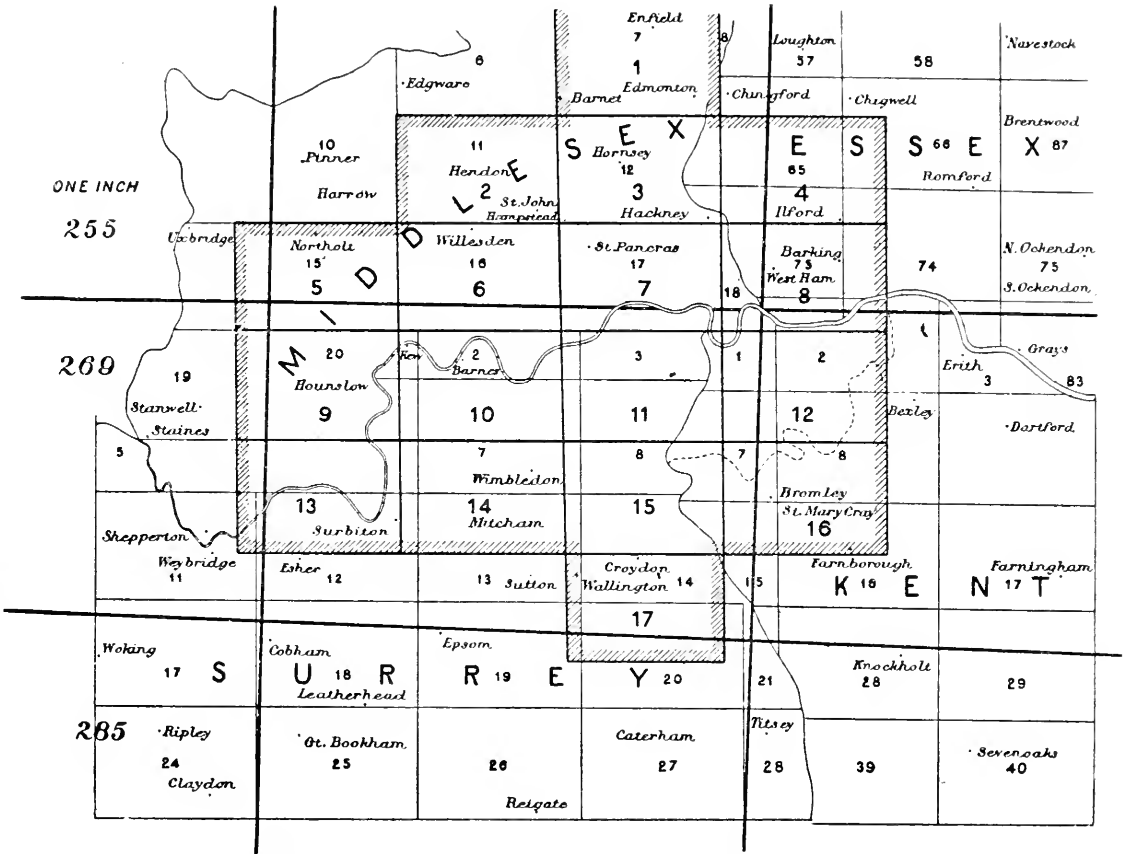
OF THE

LONDON AREA.

N.B.—The larger figures within the shaded area refer to the London County Maps.

The smaller figures indicate the numbers of the County Maps of Middlesex, Essex, Kent, and Surrey.

The thickest lines mark the divisions of the one-inch Sheets 255, 256, 257; 269, 270, 271 285, 286, 287.



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Names of authors and other individuals are printed in small capitals.

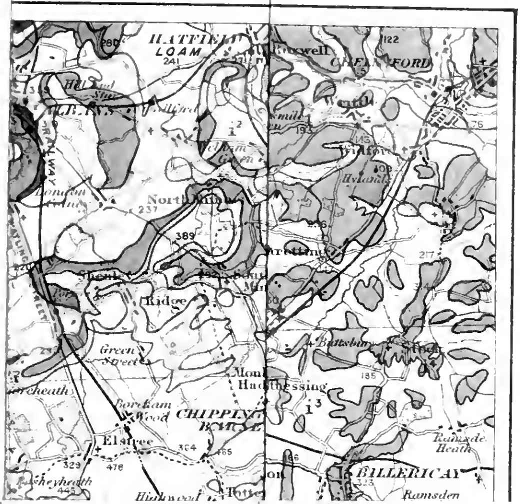
The figures in **clarendon** refer to the principal heights (in feet) above Ordnance Datum of the localities. Names are spelt according to the New Series of Ordnance Survey Maps.

The letters which follow the names of places refer to the geological formations there represented, as follows :—

A.	Alluvium (Marshland).
B.	Bagshot and Barton Sands.
Bcl.	Boulder Clay.
Bl.	Blackheath Beds (gravel).
Bm.	Bracklesham Beds (clay and sand).
C.	Chalk.
Clf.	Clay-with-flints and Loam.
G.	Gravel and Sand of Higher Grounds.
Glt.	Gault (clay).
H.	Hastings Beds (sand and clay).
L.	London Clay.
Lg.	Lower Greensand.
Lm.	Loam (Brickearth).
T.	Thanet Sand.
Ug.	Upper Greensand.
Vg.	Valley Gravel.
W.	Woolwich and Reading Beds (mixed gravel, sand and clay).
Wd.	Weald Clay.

Places to which no reference pages are given are not mentioned in the text, but most of them are included in the Map accompanying this work.

SHEETS { 15. 16. 19. 20.



MAP OF THE
SUB-SOILS
OF THE
COUNTRY AROUND LONDON,
1906.

Scale 1 Inch = 4 Miles

0 1 2 3 4

CLAYEY SERIES

Marshland

1^2 *Clay*

h^3 *Clay Gault*

h^1 *Clay Weald Clay*

Stony & Chalky Clay

Clay with Flints &c

Loam

GRAVELLY SERIES

1^1 *Clay Loam & Sand*

1^{b-a} *Sand Gravel & Clay*

Gravel & Sand of Valleys

Gravel & Sand of Higher Grounds

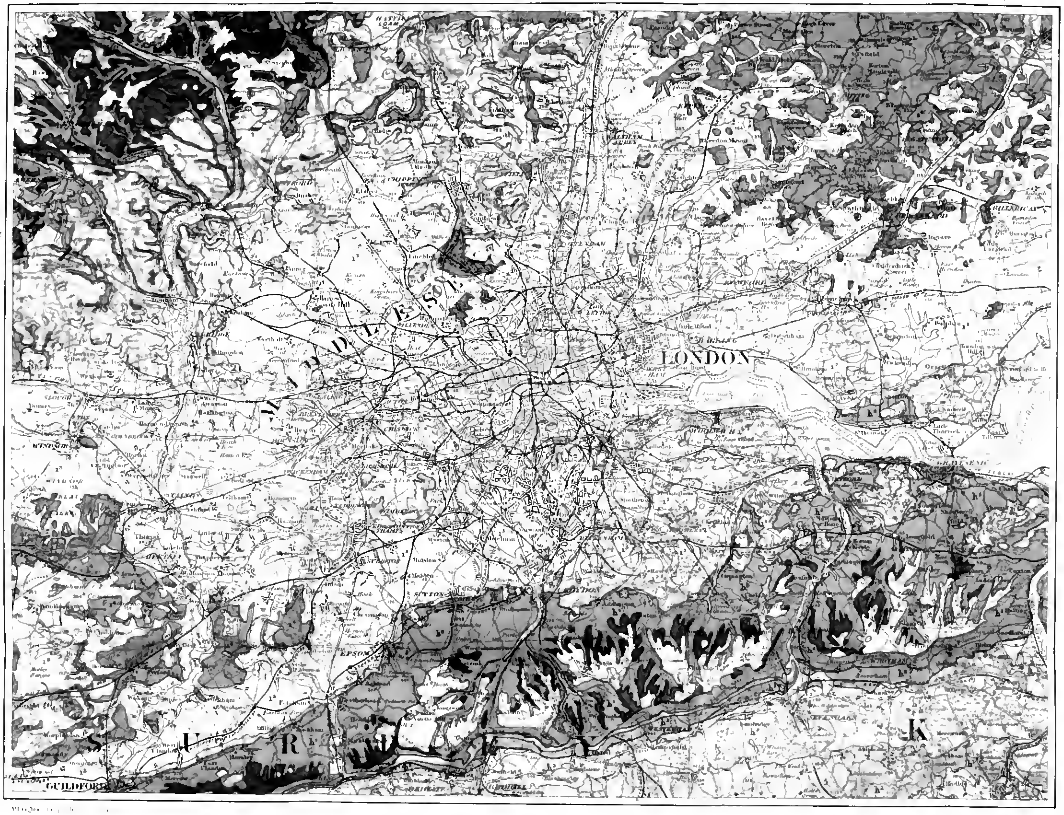
SANDY SERIES

1^{c-e} *Sand & Gravel*

h^2 *Sand Sandstone &c*

h^4 *Sand & Sandstone*

h^5 *Limestone Chalk*



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